# NOTE

This Microfiche meets the quality requirements of the American National Standard for Microfiche of Documents (ANSI PH5.9-1975). However, because of imperfections in the document from which it was made, it contains images that are illegible or difficult to read. The source document for this microfiche is the best copy that could be obtained prior to filming.

CIS

Congressional Information Service,
Washington, D.C.

S. Hrg. 100-556—Pt. 2

# USE OF THE INTERSTATE HIGHWAY SYSTEM RIGHT-OF-WAY FOR MAGNETIC LEVITATION HIGH SPEED TRANSPORTATION SYSTEMS

## HEARING

BEFORE THE

SUBCOMMITTEE ON WATER RESOURCES,
TRANSPORTATION, AND INFRASTRUCTURE

OF THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

SECOND SESSION

ON

## S. 2072

A BILL TO AMEND TITLE 23, U.S. CODE, TO AUTHORIZE THE USE OF RIGHTS-OF-WAY ALONG FEDERAL-AID HIGHWAYS FOR THE CONSTRUCTION OF TRANSPORTATION SYSTEMS THAT WILL BE PART OF THE FEDERAL-AID HIGHWAY SYSTEM

SEPTEMBER 28, 1988

## PART 2

Printed for the use of the
Committee on Environment and Public Works

U.S. GOVERNMENT PRINTING OFFICE
91-384 WASHINGTON : 1988

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

S321-10

## COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

QUENTIN N. BURDICK, North Dakota, *Chairman*

DANIEL PATRICK MOYNIHAN, New York
GEORGE J. MITCHELL, Maine
MAX BAUCUS, Montana
FRANK R. LAUTENBERG, New Jersey
JOHN B. BREAUX, Louisiana
BARBARA A. MIKULSKI, Maryland
HARRY REID, Nevada
BOB GRAHAM, Florida

ROBERT T. STAFFORD, Vermont
JOHN H. CHAFEE, Rhode Island
ALAN K. SIMPSON, Wyoming
STEVE SYMMS, Idaho
DAVE DURENBERGER, Minnesota
JOHN W. WARNER, Virginia
LARRY PRESSLER, South Dakota

PETER D. PROWITT, *Staff Director*
BAILEY GUARD, *Minority Staff Director*

---

### SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION, AND INFRASTRUCTURE

DANIEL PATRICK MOYNIHAN, New York, *Chairman*

QUENTIN N. BURDICK, North Dakota
GEORGE J. MITCHELL, Maine
JOHN B. BREAUX, Louisiana
BARBARA A. MIKULSKI, Maryland
HARRY REID, Nevada
BOB GRAHAM, Florida

STEVE SYMMS, Idaho
ROBERT T. STAFFORD, Vermont
JOHN H. CHAFEE, Rhode Island
DAVE DURENBERGER, Minnesota
JOHN W. WARNER, Virginia
LARRY PRESSLER, South Dakota

# CONTENTS

## OPENING STATEMENTS

Page

Durenberger, Hon. Dave, U.S. Senator from the State of Minnesota .......... 7
Graham, Hon. Bob, U.S. Senator from the State of Florida .......... 62
Moynihan, Hon. Daniel Patrick, U.S. Senator from the State of New York .......... 1
Reid, Hon. Harry, U.S. Senator from the State of Nevada .......... 6

## WITNESSES

Choate, Patrick, director of policy analysis, TRW, Inc .......... 69
  Written statement .......... 101
Danby, Gordon, Brookhaven National Laboratory .......... 59
Parsons, Robert E., manager, program for advanced technology, Institute of Transportation Studies, University of California .......... 67
  Written statement .......... 92
Powell, James R., Brookhaven National Laboratory .......... 56
Rush, David H., Member, Florida High Speed Rail Transportation Commission .......... 64
  Written statement .......... 79

## ADDITIONAL MATERIAL

Bement, Arden L. Jr., vice president, technical resources, TRW, Inc., statement of .......... 104
S. 2072 .......... 113

# USE OF THE INTERSTATE HIGHWAY SYSTEM RIGHT-OF-WAY FOR MAGNETIC LEVITATION HIGH SPEED TRANSPORTATION SYSTEMS

---

WEDNESDAY, SEPTEMBER 28, 1988

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION,
AND INFRASTRUCTURE,
*Washington, DC.*

The subcommittee met, pursuant to recess, at 9:36 a.m., in room 406, Dirksen Senate Office Building, Hon. Daniel Patrick Moynihan (chairman of the subcommittee) presiding.

Present: Senators Moynihan, Reid, Graham, and Chafee.

## OPENING STATEMENT OF HON. DANIEL PATRICK MOYNIHAN, U.S. SENATOR FROM THE STATE OF NEW YORK

Senator MOYNIHAN. May I say good morning to our distinguished witnesses, our guests, and to the committee staff.

Dr. Rush just presented me with a little calling card he uses, which is a reject of one of the chips they make at Aptek. He said to me that this room wouldn't hold the blueprints for the circuitry on this little affair here, it's 10 years old, but an element of what we're talking about this morning.

I have a statement which I'll place in the record, but to just lay out for you gentlemen what it is we are doing here in the last of three hearings which we have held in this Congress and have set ourselves in a situation where we now very confident about how we're going to move in the years to come.

Last October, we introduced, with the inevitable acronym, the Federal Advanced Superconducting Transportation Act, the FAST Act, which would authorize research funding by the Federal Government into the research and production of an operable Maglev ground transportation system. And then later, in February, I introduced another bill which technically is the bill we're hearing on today, S. 2072, which directs the Secretary of Transportation to issue permits that will allow the use of the rights-of-way of the Interstate Highway System for a magnetic levitation system.

We have had two hearings, as I indicated. I had the first one here when Doctors Powell and Danby came. And they repeat the theme two, three, fourfold, that this almost certainly is going to be the defining characteristic mode of transportation in the next century. It just seems to be one of those things that's coming. The railroad came, the automobile came, and the airplane came. Now this is coming.

Now this, its aspects are so evident to this committee panel, I'm not going to repeat them. But the problems of congestion, the problems of air pollution, the general need to move long distances in this country, as in other countries, although the Germans may be the first persons to put a system into play. I just make this argument.

After our hearing in New York, we had a wonderful column by Russell Baker in the New York Times, in which it was discussed—Rush may have noticed this—but when Senator Graham was Governor, he began the work on studying the transportation needs of Florida in the years ahead, and I think he estimated that by the year 2010 it was going to take 22 lanes of interstate highway to move projected traffic from Miami to Orlando, and that Baker had one of his inspired moments in which he—the column was entitled—as a matter of fact, let's have that put it in the record. From World War II, that rather terse announcement in World War II, it said, "One of our States is Missing," and what was going to happen here if this keeps going.

Another aspect of the queries we've had so far, which is here again, here perhaps most notably, you have a powerful technology, conceived, devised, published in the United States, and now being produced abroad. It's all very well to say that some firms in the country apparently produce the VCR, and the Japanese will be the manufacturer. Well, VCR's aren't the defining element of a civilization. Well, maybe they are, more than we should think, but not altogether. And in the exact same mode, you have the high definition television, which apparently again, a product approved and developed, here, being developed abroad. How we'll work it out with the FCC is not yet finally clear. But we obviously have this pattern.

These are two large events to extrapolate, but something of this pattern seems to have fallen to the British half a century or so ago, and their science continued very superb, and yet it didn't translate into economic events.

And that is something to pay attention to. We have heard more and more, and we have been able to break through a kind of silence as Time Magazine, and the New York Times, not to mention the McGraw Hill publications and others, the Newhouse papers, have started, using photographs of the Japanese prototypes, German prototypes. You get stories about what they're doing. And it's just likely that in the combination as you keep encountering the phenomena of where are you going to find air space, where are you going to find ground space, what are you going to do about air pollution, and such. This is an idea whose time has come. I have no doubt about it. We're going to be building and using these. We're going to build one from Las Vegas to Los Angeles. I think that is, at this point, about the most advanced project, is it not? And then, of course, the Florida projects which we're going to hear about today.

I want to hear from my colleague, Senator Reid. I first simply want to say, just for the record, who our witnesses are, and we welcome back Doctors Powell and Danby, who are the pioneers in this field. We have Pat Choate, who is the Vice President of Policy Analysis at TRW, and is an internationally known authority on infrastructure issues and on our trade. And David Rush, who will be introduced later by Senator Graham, is a member of the Florida high speed rail commission, and we'll hear more about him from Mr. Graham.

Robert Parsons, who is the Director of the Institute of Transportation Studies, at the University of California at Berkeley, has the unique perspective of having been a senior government official when the Maglev studies first began.

I'd like to tell you it was I who arranged that building up at MIT to become the research institute when it couldn't be used for weaponry. And then it all seems to have disappeared. But you're doing the study, aren't you, Mr. Parsons—Professor Reid will know—for the Las Vegas-Southern California project?

Mr. PARSONS. I conducted that study on leave of absence from the University, yes, sir.

Senator MOYNIHAN. And so we are all here together, and I am going to turn now to my distinguished colleague.

[Senator Moynihan's statement and the column by Russell Baker follow:]

### OPENING STATEMENT OF HON. DANIEL PATRICK MOYNIHAN, U.S. SENATOR FROM THE STATE OF NEW YORK

Good morning. I would like to welcome the invited witnesses and guests to this hearing of the Subcommittee on Water Resources, Transportation and Infrastructure. Our purpose today is to continue with our consideration of the application of magnetic levitation (maglev) transportation to the interstate highway system's rights-of-way.

On October 16, 1987, I introduced S. 1794, the Federal Advanced Superconducting Transportation Act of 1987—I call this the FAST Act—which would authorize funding for research into the production of an operable maglev ground transportation system. Subsequently, on February 18, 1988, I introduced legislation (S. 2072) to direct the Secretary of Transportation to issue regulations to permit the construction of magnetic levitation on the interstate rights-of-way.

Thus far, the Subcommittee has held two hearings, on January 21 and February 26, 1988, that have examined the technology of magnetic levitation transportation and certain questions about how it might be adapted to the interstate system.

As a result of the two hearings that we have already conducted, the Subcommittee has learned of the tremendous potential of magnetic levitation transportation. We have heard testimony from distinguished scientists about the practicality of magnet levitation technology, that Japan and Germany have poured over $1 billion into establishing maglev prototypes, and the potential interest of U.S. industry in maglev, if proper Federal leadership could be established.

It is for this last purpose, to begin a serious debate on the need for a Federal role, that I introduced the FAST Act and S. 2072. This legislation provides a blue print for a Federal program to develop maglev technology and to assist the States in implementing maglev transportation corridors. As I said at the time I introduced this legislation, we have not experienced a quantum leap in transportation technology since the Wright Brothers flew at Kitty Hawk in 1903. Maglev provides us with such an opportunity.

Nevertheless, despite the fact that maglev was conceived in the United States, it is the Japanese and Germans who have taken the lead in developing it. Why? This is a nagging question, and one that our hearings are intended to address. Still, it is clear that part of the problem has been insufficient Federal leadership.

Now is the time to restore our effort to pioneer maglev, the next generation of transportation. Now is the time to remind ourselves that, as President Kennedy once said to the nation in the context of the space race, "[W]hile we cannot guarantee that we shall one day be first, we can guarantee that any failure to make this effort will make us last."

We are not that far behind. Indeed, many of our States, feeling the acute pressure from transportation congestion on our highways and at our airports, have persevered in their own efforts to establish new ground transportation technology, including maglev.

It remains, however, crucial for the Federal government to respond to the transportation and the infrastructure challenge: maglev is one such response.

After all, transportation is a fundamental component of our economy. No transportation system—from the canals and railroads of the nineteenth century to the highways and airports of the twentieth century—has ever been developed without a strong Federal role. The challenge before us today is whether the United States will establish a dominant maglev transportation system for the twenty-first century, or whether Japan and Germany will do it instead.

I am delighted to present our witnesses today.

Pat Choate is Vice President for Policy Analysis at TRW. Mr. Choate is a noted expert on infrastructure issues and on our international trade situation. He will address the important challenge posed to our economy by the maglev efforts of Japan and Germany, and why our failure to establish a US maglev industry could be very damaging to our economy.

In addition, Mr. David Rush, a distinguished business executive from Florida and a member of the Flordia High Speed Rail Commission, will present his views of maglev. Mr. Rush, also the chairman of Florida's High Technology and Industrial Council, will explain the impressive effort undertaken by Florida towards establishing maglev in that State.

I should also note that it was Senator Bob Graham, then Governor Graham, who established Florida's commission, and who is a pioneer in recognizing the need for improved ground transportation systems.

Senator Graham realized that something would have to be done if projections that by the year 2020 Interstate 95 would have to be 44-lanes wide to accommodate the automobile traffic from Miami to Fort Lauderdale were not to be realized! Indeed, this mind boggling possibility caused Russell Baker to remark in the New York Times that:

"Anything this dreadful can surely be stopped if somebody puts a mind to it. And somebody certainly should before the rest of the country is as disappeared as Florida. It would be good if Candidates Bush and Dukakis tried to create some pressure to save a little of the country from Burial under the 44-lane highway."

Perhaps Mr. Rush will tell us how maglev can help Florida from being disappeared, as Mr. Baker puts it. And the same goes from the rest of the country.

Our next witness will be Mr. Robert Parsons, Manager, Institute of Transportation Studies, University of California at Berkeley. Mr. Parsons has the unique perspective of having been a senior government official when the Federal Government terminated its modest maglev effort in 1975. He has managed the maglev study for the Las Vegas-Southern California project.

I am looking forward to Mr. Parsons views on the problems with the current Federal effort towards transportation development, and how we can address these needs.

Finally, the Subcommittee is delighted to have Dr. James Powell and Dr. Gordon Danby of the Brookhaven National Laboratory of Long Island with us again today. As the inventors of maglev in the 1960s, they are true heroes of American science. Unfortunately, as appears increasingly to be the case, their contributions have been better recognized in Japan and Germany.

I am most gratified to be able to announce today that Drs. Powell and Danby have agreed to coordinate a major study on the applicability of magnetic levitation to the interstate highway system. An advisory group has been assembled of distinguished scientists, economists, and business people from around the country to help complete the study.

It is my intention to present this study to the next President of the United States early in 1989. I hope that the entire Subcommittee, and indeed the Full Committee, will want to join with me in this effort. It is past the time that we can afford to do nothing about maglev, and the next administration will need to exercise leadership on this issue if the benefits of Drs. Powell's and Danby's genius are to accrue to the American people.

I look forward to hearing about this study, and I trust that it will not be too long before their profound contributions are fully appreciated by this country. Soon Brookhaven will be known as the Kitty Hawk of maglev.

[From the New York Times, May 11, 1988]

## One of Our States Is Missing

(By Russell Baker)

Senator Moynihan, whose public duties include trying to save the country from coming to a complete standstill, says that by the year 2020, Interstate 95 will have to be 44 lanes wide to carry the traffic between Fort Lauderdale and Miami.

"Pretty soon there won't be anything left of Florida," he says.

It's hard to weep about that because there's almost nothing left of Florida already. Whatever that thing is that's spreading down there may be interesting, or fun, or beloved by those sitting in its air-conditioned condos and traffic jams, but Florida it isn't.

Florida was still mostly there in the 1940's, and there was even a good bit of it remaining in the 1960's, but now there's hardly enough Florida left to fill a glass display case in the Smithsonian.

Robert Frost once said it doesn't take man long to use up a continent. The consumption of Florida shows he can do it practically overnight if the territory is humid and sandy and its winters are milder than Cleveland's.

Senator Moynihan's ruminations about the dubious future down there are evoked by his interest in developing new forms of transportation. A member of the Senate Public Works Committee, he is trying to stir up interest in experimental magnetic-levitation vehicles.

This is hard going because the Government is committed to sticking with cars and airplanes to the bitter end. Forty-four lanes of traffic on I-95. Meantime, why spend money experimenting in Buck Rogers stuff like magnetic-levitation vehicles? Star Wars, yes; traffic solutions, no.

The American traffic solution is to widen the road. This is happening all over the once beautiful farmland of the Middle Atlantic states. Dirt roads barely wide enough for two cars to pass nervously are being paved with two broad lanes. Two-lane roads are swelling to four lanes with median strips, and four-lane divided highways are being widened to eight lanes.

The result is always the same. Better roads lure more people to settle alongside them, bringing more cars, which jam the better roads. This angers the people in the traffic jams, who elect new politicians promising to solve the traffic problem by building better roads.

This cycle of destruction has been continual since World War II. You'd think somebody would have realized by now that building better roads doesn't work. Just uses up the continent that much faster.

But everyone, of course, does realize that it doesn't work. We keep on doing it anyhow. For one thing, building highways is something we do well; everybody likes doing what he's good at, even though it leads to a terrible mess.

So we tacitly consent to being duped. We know the better roads being promised will relieve the traffic jam, only briefly before doubling its intensity, but we elect the better-roads ticket anyhow.

For a couple of years the traffic gets even worse because of the construction work. Finally comes the year when traffic flows contentedly. But what is this!

You have just discovered yourself surrounded by vast, raw clots of housing developments named Greenery Glen, Forested Fantasy and Wistful Woods. Day after that the new jamfree, eight-lane highway is jammed halfway to Metropolis Bypass. Furious, aren't you? Time to vote for the new better-roads ticket.

So we head inexorably toward the 44-lane highway, cheered on by the incanfation of real-estate developers and asphalt tycoons: no use crying, folks, because growth and development cannot be stopped, and anyhow it's good for you.

Why can't growth and development be stopped? In my experience, growth and development raise your taxes, make a shameful mess on the countryside and disperse people from the civilizing influence of city living to barren new communities which bind their victims to lifetimes of driving and offer so few rewards that the breakdown of the TV set becomes a catastrophe.

Anything this dreadful can surely be stopped if somebody puts a mind to it. And somebody certainly should before the rest of the country is as disappeared as Florida.

It would be good if Candidates Bush and Dukakis tried to create some pressure to save a little of the country from burial under the 44-lane highway. A proposal or two for saving a little bit of America for another day would certainly be more invigorating than the tired old campaign gas they have been emitting so far.

Senator Moynihan, with magnetic levitation, is at least trying. Dukakis and Bush should study his lead. They both need levitating.

## OPENING STATEMENT OF HON. HARRY REID, U.S. SENATOR FROM THE STATE OF NEVADA

Senator REID. Thank you very much, Mr. Chairman.

Before I turn to my short statement, I want to mention that we've had several hearings in this room in the last week or so, and the room has just been packed. Those hearings were about issues that people know a little bit about, such as, global warming, and air pollution, and others.

Mr. Chairman, I say this now and I've told you this privately, you have been a leader in directing attention to the technology and scheduling hearings under your auspices. Here is a program that could go far to do away with the need for bigger airports, more automobiles, more highways, but attendance is low. It's something that is going to take some education, and I think part of that is going to have to come from this committee and this subcommittee.

So I am pleased to be here today to hear testimony on the development of this magnetic levitation system along Federal Highway rights-of-way. Again, not a very glamorous subject, but I think one that's so critical to allowing this program to go forward.

I, in my prepared statement, Mr. Chairman, I stated that you have been a leader in this area and I admire your foresight, and I underscore and underline that.

Our Nation's airports are overcrowded, and the air traffic controllers, who ensure our safety in the sky, are overworked. The commercial airlines are competing with the military and the general aviation community for elbow room in the limited airspace above our country. That's becoming more complex, more dangerous all the time.

I spoke with a pilot one day whose general route was to go into L.A. He lived in Nevada. He said he was afraid every time he went in there.

The highways near our major metropolitan centers are packed with bumper-to-bumper traffic. This gridlock threatens to stifle the economic expansion of the country.

As we approach the 21st century we are faced with the problem of moving an ever-growing population within the limitations of our finite transportation capacity. So we have to look forward and seek alternatives.

Earlier this year this subcommittee heard the testimony of two scientists who were tired of the traffic and decided to do something about it, who helped develop this advanced technology. I found their testimony to be fascinating. The development of sophisticated high-speed ground transportation systems is an essential step forward to addressing our transportation needs.

One of the witnesses today, David H. Rush, will report on the status of Florida's efforts to bring Maglev technology to the State of Florida, with the help of Senators Graham and Chiles.

We in Nevada consider ourselves leaders in the area, too. As the Chairman mentioned, on September 14, the Nevada-California Super Speed Ground Transportation Commission held its first meeting. This is a group that has been approved by the Nevada

State Legislature and the California State Legislature. That commission will continue to work until a high-speed ground transportation system is built to service the Las Vegas to Southern California corridor. The Maglev technology is one of the primary systems being considered. Construction of this system is scheduled to begin in 1991. In addition, construction of a one-mile Maglev demonstration project from Cashman Field, which is an old baseball field, now a new baseball field, convention area in the Las Vegas area, to the Glitter Gulch, downtown Las Vegas, away from the strip has already begun. They've already started the grading, and that project is under way. This project is scheduled to be completed by 1991. Another 2½-mile project is under consideration, to go from where this one stops, out to the strip. And the plans have been drawn.

So making Federal Highway rights-of-way available to these kinds of advanced transportation projects will facilitate the development and help solve our Nation's transportation crisis.

I look forward to this testimony. I would, in advance, apologize, Mr. Chairman. I am on an Appropriations conference that is to begin at 10:30, so I will have to leave.

Senator MOYNIHAN. We understand that.

Before we call upon our witnesses, I want to acknowledge a statement from Senator Durenberger who, unfortunately, could not be with us today. His statement and attachments will be included in the record of today's hearing.

[The statement and attachments follow:]

### OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Mr. Chairman, thank you for calling this, as well as the previous hearings. As the Chairman of the U.S.-Japan Rail Congress and the U.S.-France Rail Congress, I have always been keenly interested in efforts to push this country back into a more active high speed rail research and development program. And as you are now discovering, Senator Moynihan, it was a fairly lonely effort.

The individuals who appear before the Committee today will have a great deal to say about the future of magnetic levitation and other high speed rail technology in this nation. They represent the best of this country's past and present efforts to develop a greater United States role in this emerging technology. And it is important that they understand that, at the very least, they have the support of this Committee.

At this point I would like to insert into the record several technical papers that were prepared by a number of prominent Japanese researchers. When my friends in Japan heard of this hearing, they made a point to delivery these to me. I am hopeful that they will add a little more weight to the impressive amount of information these hearings have already generated.

# THE ROLE OF SUPERCONDUCTIVITY IN TRANSPORTATION

Yoshihiro Kyotani

Technova Inc.

Tokyo, Japan

## ABSTRACT

A magnetically levitated vehicle now under research and development by the Japan Railway Technical Research Institute utilizes superconducting magnetic levitation and linear synchronous motor (LSM) propulsion. The 44-seat MLU002, 22 meters long and weighing 17 tons, is now being tested on the 7-km Miyazaki test track. An electromagnetic thrust ship is also under research and development by the Japan Shipbuilding Industry Foundation. The building of a technologically feasible FS ship has been planned using LSM superconducting magnets to assist the take-off of a winged launch vehicle. Furthermore, many superconducting applications for transportation have been considered and are being developed around the world.

## Superconducting Magnetically Levitated Train: Miyazaki Test Track

Japan Railways has constructed a test track south of Hyuga city in Miyazaki Prefecture, and uses this track to test an experimental train levitated by superconducting magnets. The Miyazaki test track is seven kilometers long, and the entire length is elevated. Test runs start from the test center and proceed down a 5/1000 gradient. There is a power station located at about the midpoint of the track, after which the train proceeds through a 10,000 meter radius curve to the end of the track.

## Running tests

The first automatic test vehicle run on the Miyazaki test track was the 13.5 meter long, 10-ton ML500 (Fig. 1). This vehicle was equipped with sixteen superconducting coils.

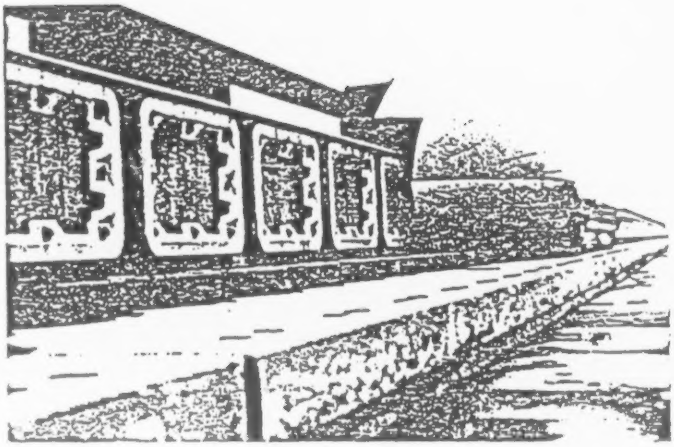


Fig. 1 ML500 levitated running

ML500 tests began in 1977, and included simulated tunnel runs and experiments in which helium refrigerators were carried. In December 1979, the target of 500 km/h was broken with a record speed of 512 km/h.

These tests were followed by multiple car runs and manned runs, after which the design of inverted-T guideway shown at the left in Fig. 2 was changed to the U-shaped guideway shown on the right.

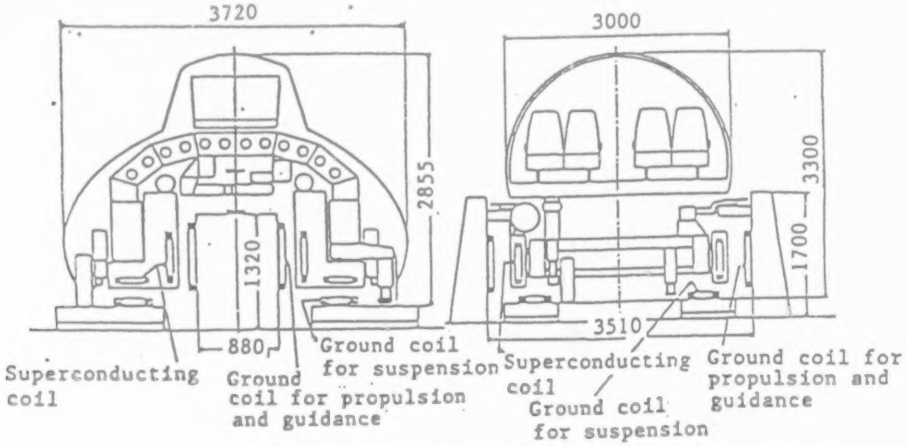

3720
2855
1320
880
Superconducting coil
Ground coil for propulsion and guidance
Ground coil for suspension
3000
3300
1700
3510
Superconducting coil
Ground coil for suspension
Ground coil for propulsion and guidance

Fig. 2 From inverted T shaped guideway to U shaped guideway

The most significant feature of this change concerned the design of the superconducting magnet. With the inverted-T guideway, the superconducting magnet consisted of two types of superconducting coils, one for propulsion and guidance and the other for suspension, as shown on the left. These three functions were combined into a single superconducting coil providing propulsion, guidance, and suspension. This design change helped reduce vehicle weight, and was incorporated into a new vehicle named the MLU001.

The MLU001 was configured as shown in Fig. 3. A single car has a base length of 10 meters and weighs 10 tons. Each car is divided into two rooms. One room is the equipment room containing the storage cells, inverter, ground-linked data communications equipment, and ~~other~~ equipment. The other room was the instrumentation room so that the train could be manned for supervision and data-gathering purposes. The seats were removed for the initial test runs, and then installed for manned experimental runs.

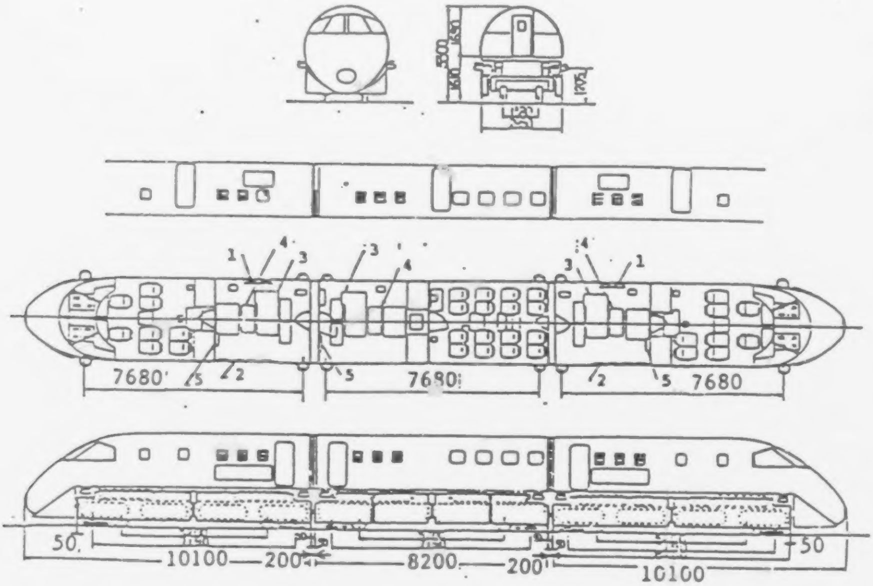


Fig. 3  General views of the connected MLU001 test vehicles

Fig. 4 is a photograph of a test run with three linked MLU001 cars. The shape of the body was determined on the basis of wind tunnel experiments and the results of trial runs with the earlier ML500. Trains in commercial service, however, must be able to run in both directions, and tests to develop an accommodating body design were conducted. As stated earlier, this train uses superconducting coils combining propulsion, guidance, and suspension in each coil. Eight such coils are installed on each car.

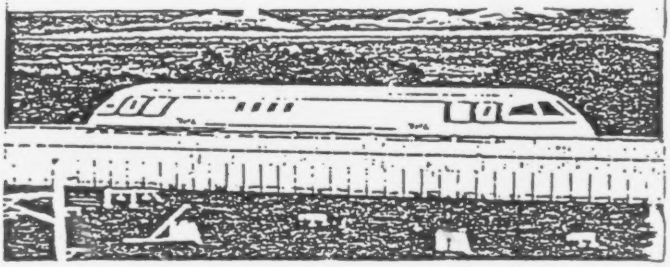


Fig. 4 MLU001 levitated running

Fig. 5 shows the MLU001 superconducting coil and helium refrigerator assembly used in the MLU001. A niobium-titanium alloy wire with a copper ratio of 2 is used in the superconducting coil. The coil has a magnetomotive force of 700 kA. Two such coils are installed in a low temperature container, and indirect cooling is used to maintain a low coil temperature. The helium refrigerator used here weighs 40 kg. The total weight of the superconducting coil and helium refrigerator assembly shown in the figure is 700 kg.

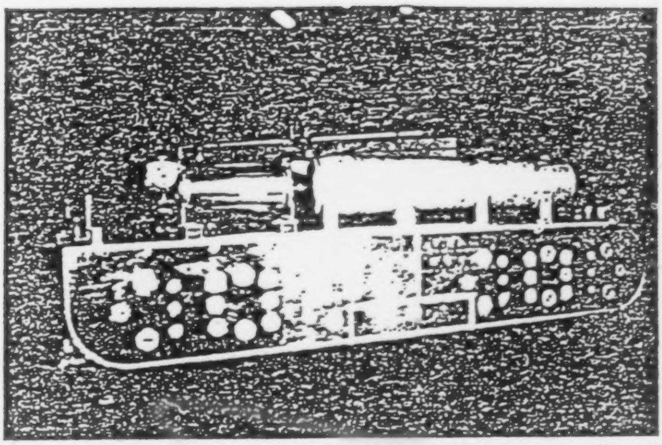


Fig. 5 Superconducting magnet and Helium Refrigerator for MLU001

The center cars use a single coil-type superconducting magnet in which only one superconducting coil is installed in the low temperature container, and a helium refrigerator is integrated with the low temperature container. From this stage of development, the Claude cycle helium refrigerator used previously was complemented by a new Stirling cycle refrigerator. A refrigerating cycle with a Joule-Thompson valve was used as the technology then available was not able to reach 4°K using only the Stirling cycle.

In addition to these advances in low temperature research and development, the Miyazaki Test Center was also conducting parallel experiments to gather information on the construction and maintenance requirements of commercial lines.

The span between girders of the test track was 15.4 meters. Vertical and lateral deflection control tests were conducted as shown in Fig. 6. As the results of these tests revealed no problems with respect to operation and showed a good correlation to simulations, a deflection control test in which the girder positions were changed as shown in the bottom of Fig. 6 was conducted. The natural vertical frequency of the body is approximately 1.5 Hz, causing the vehicle to resonate at approximately 300 km/h. The girder span length shown in Fig. 6 was used to interrupt the harmonic frequency, and thereby prevent vehicle resonance.

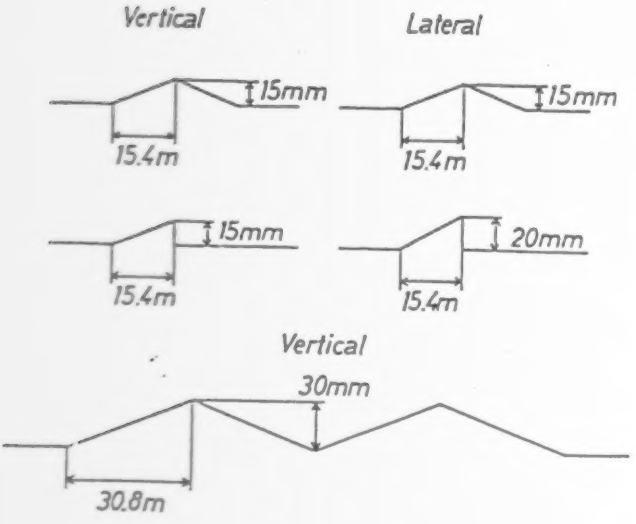


Fig. 6 Deflection control test (example)

Two MLU001 cars were connected and run down this modified guideway, and there was only one point at which the normal 10 cm suspension momentarily dropped to 7 cm. Also, vibrations were attenuated and vibration damping was shown to be sufficient with the vehicle vibrating only once after passing the deflection point. I think it is safe to say that the greatest feature of superconducting magnetic levitation is this ability to minimize vibration and maintain a constant 10 cm suspension without extra control devices.

These results also showed that a fair degree of deflection in the girder joints does not interfere. Low rigidity girders were therefore manufactured and incorporated into the test track. These girders are still being used as part of a long-term durability study, and no problems have been confirmed so far. Use of these girders is expected to dramatically reduce construction costs.

To determine what effect installing the coils on the girders at irregular intervals would have on the train, the coil positions were changed as shown in Fig. 7 and operating tests were run. This test might be seen as willful maliciousness or tampering. This test demonstrated the safety of the superconducting magnetic levitation transportation system, and provided data essential to system maintenance.

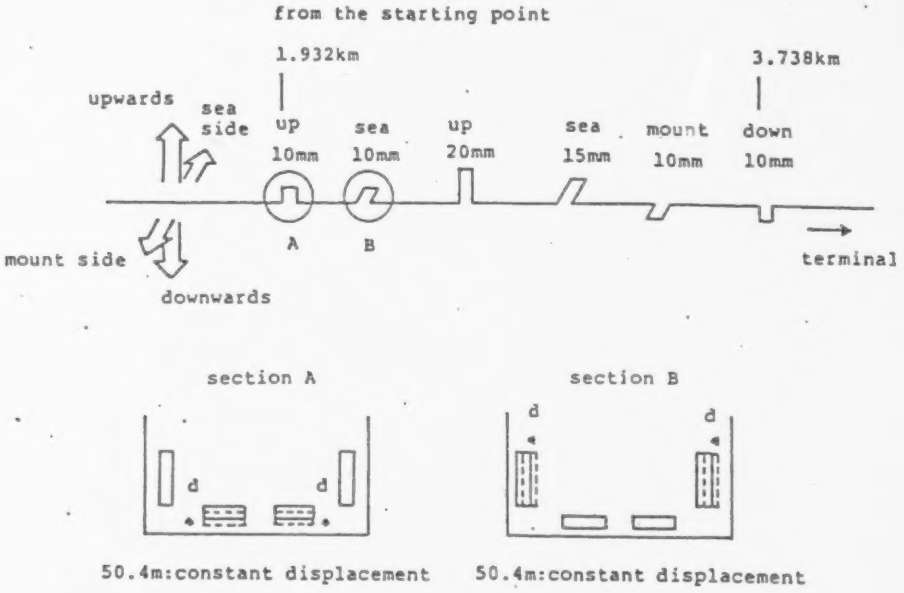

from the starting point
1.932km
3.738km
upwards
sea side
up 10mm
sea 10mm
up 20mm
sea 15mm
mount 10mm
down 10mm
mount side
downwards
A
B
terminal
section A
section B
d
d
d
d
50.4m:constant displacement
50.4m:constant displacement

Fig. 7 Guideway coil irregularities

In February 1987, two linked MLU001 cars carrying myself and two others recorded a record maximum speed of 400.8 km/h. In manned tests, the train was stopped within 6 km to provide an extra margin of safety. This means that a maximum speed of 400 km/h could not have been reached with acceleration and deceleration of less than 0.4 g. Although the longitudinal ride could not be considered good, the ride was, in general, comfortable. This may be attributable to the added confidence gained from knowing that no extra control devices were needed for the vehicle suspension and guidance system, combined with that gained from the use of superconducting magnets maintaining 10 cm levitation at all times.

Repeated tests with the MLU001 and trial runs with visitors from Japan and abroad have provided a wealth of valuable information.

Research into commercial vehicles has also proceeded smoothly, and we have now reached the stage where trial runs using an almost commercial prototype vehicle are needed. These advances enabled us to obtain additional research funds from supporting concerns, and to proceed with the production of an advanced prototype of the MLU001.

On March 28, 1987, just before the Japan National Railway was privatized, JNR announced the MLU002 prototype at the Miyazaki Test Center. Fig. 8 is a photograph taken that day. Journalists from around the world were present for this announcement.

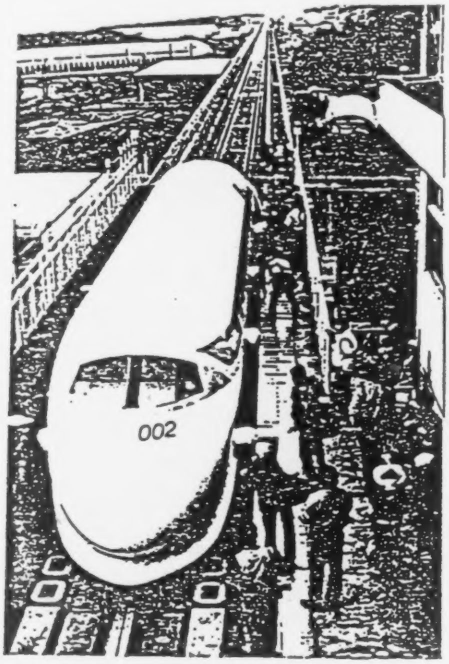


Fig. 8 Prototype vehicle, MLU002

As shown in Fig. 9, the MLU002 is 22 m long, 3 m wide, 3.7 m high, weighs 17 tons, and has 44 seats. The cars were streamlined at the ends to reduce air resistance, resulting in a comparatively small number of seats relative to the total car length.

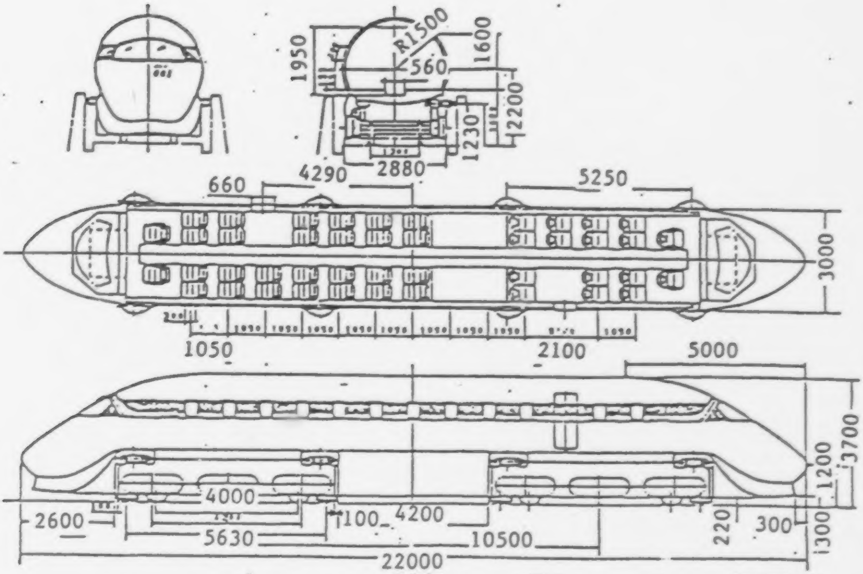


Fig. 9 General view of the MLU002 prototype vehicle

Each car has three 700-kA superconducting coils mounted on both right and left sides. As can be seen in the figure, the superconducting coils are not mounted in a continuous series from car to car in the direction of travel. This is because the cars are linked with a frame to reduce car height as much as possible in a commercial vehicle.

A niobium-titanium alloy wire with a copper ratio of 1 was used in the superconducting coils to reduce the weight.

MLU002 cars are equipped with air conditioners for the interior since the Miyazaki test track runs north-south, and it was exceedingly hot when riding the MLU001 during the summer.

The maximum magnetic flux density of the floor inside the vehicle was held to 200 gauss, but this is still high enough to affect certain common passenger items, one of which is the pacemaker. We have studied the effect of the magnetic flux density of the floor on pacemakers, and on January 23, 1988, JR Tokai Chairman Mr. Miyake volunteered to participate in this study. Mr. Miyake uses a pacemaker, and yet experienced no problems during this trial ride. The results of this potentially hazardous run were immediately announced to the press, which happily shared our view of the bright promise of the MLU002 maglev vehicle.

## Future Prospects

Interest in these magnetic levitation experiments has grown with each success and new record set with the ML500, MLU001, and MLU002, and numerous national development plans have incorporated the maglev train. Regional authorities have also shown great interest in this new means of mass transportation, and have been actively working to bring the maglev train to their region. We have nearly reached the point where the greatest obstacle to implementation is no longer technological, but political.

Fig. 10 shows a picture sent to me by an artist in Hokkaido. Talking about the picture, the accompanying letter said, "the buildings in the background show a futuristic Sapporo, and the best vehicle to connect this future Sapporo with Chitose Airport is nothing other than the superconducting magnetic levitation train." In addition to Hokkaido, other areas currently being considered for installation of the first train line include the Pacific coast of Ibaraki, Fukushima, and Miyagi prefectures, Niigata Prefecture, between Oomiya city in Saitama Prefecture and Narita International Airport in Chiba Prefecture, from Tokyo to Osaka by way of Kofu and Nagoya, a line in the Kita Kyushu area, and a line in eastern Kyushu.

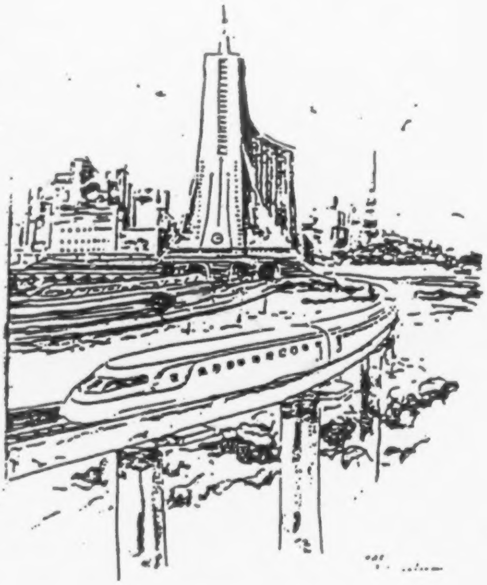


Fig. 10 Painting future Sapporo

As this shows, interest in the magnetically levitated train is high throughout Japan. The prospects for this technology in the future are excellent, and related research is also being conducted in many other nations.

One such example is the "super subway" discussed in a recent issue of 'Science Digest'. As discussed in the introduction, the basic designed is along the same lines as the "Planetran". As proposed by Dr. Salter, the Planetran would travel from New York to Los Angeles in only 21 minutes, but the version discussed in this article would however take 54 minutes. A superconducting magnetic levitation and linear synchronous motor propulsion vehicle travelling through a vacuum tube, the super subway train could travel at a maximum speed of 9600 km/h, a speed which is no longer so far from reality. At a time when concerns about environmental and atmospheric pollution are rising, it is no exaggeration to say that the time has come for a mode of super high speed transportation which is safe, comfortable, and nonpolluting. What's more, the best potential means of realizing this goal is now at hand in the form of commercially-viable superconductivity.

Other applications for superconductivity in land-based transportation are being studied in addition to the superconducting magnetic levitation vehicle. For example, a new form of transportation, which is neither motor vehicle nor train, may be realized by applying superconductivity to an adapted automobile. What's more, it may be possible by operating in vacuum tubes to apply the superconducting magnetic levitation vehicle to intercontinental transportation as well as intracontinental transport. I would expect that these systems will be applied in the initial stages to moving merchandise and commercial goods instead of passengers. The oceans do, of course, already link the continents, and the application of superconductivity to marine transport is also being studied.

## At Sea: The Superconducting Thrust Ship

### Superconducting electromagnetic thrust ship

The electromagnetic thrust ship is propelled by the reaction force of the sea water from jets generated by the electromagnetic force created when a current is applied to sea water in a magnetic field. A version of this ship in which superconducting magnets are used to generate the magnetic field is called the superconducting thrust ship. Because the energy efficiency of this system rises as the field strength increases, superconducting magnets producing a strong magnetic field are preferable. Research on this ship is proceeding in Japan primarily under the auspices of the Japan Shipbuilding Industry Foundation. The research schedule has targeted 1991 as the year in which the technology for this ship should be realized. Details of this ship will be presented by Mr. Takezawa of the Japan Shipbuilding Industry Foundation in his presentation to this Congress.

Fig. 11 is a conceptual diagram of the super high speed, superconducting thrust ship.

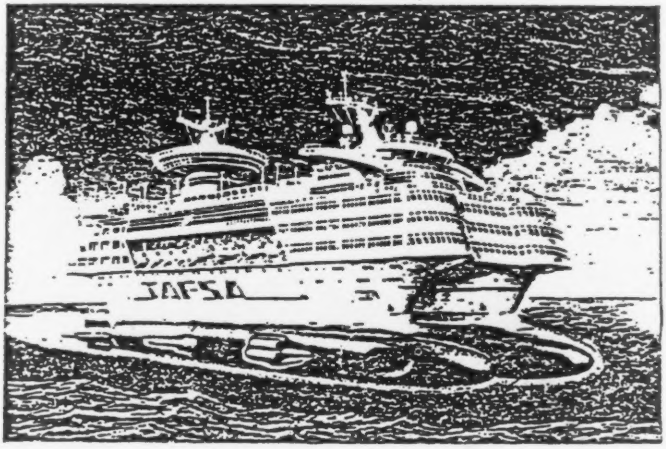


Fig. 11 A sketch of a luxury cruiser using Superconductive electromagnetic propulsion

Superconducting motor ship

The superconducting motor ship is a ship propelled by a superconducting motor driving a propeller. The superconducting motor in this ship should be compact and lightweight. Private sector research on this ship is being promoted by the Ship Equipment Association in Japan, while similar research is apparently being conducted for the military in Europe and North America.

Aeronautics and space

Applications for superconductivity in air and space are also being studied. The Lunar Mass Driver proposed by Dr. Kolm and Dr. O'Neill demonstrated the possibilities for such applications very early on. Fig. 12 shows a highly maneuverable experimental space vehicle and linear-motor assisted take-off system proposed in 1986 by Professor Nagatomo and I in Innsbruck at IAF '86. In this system, the car bodies have been removed from the MLU001 vehicles and replaced by aerodynamic fairings and a thermal shield. The winged launch vehicle is mounted over the thermal shield.

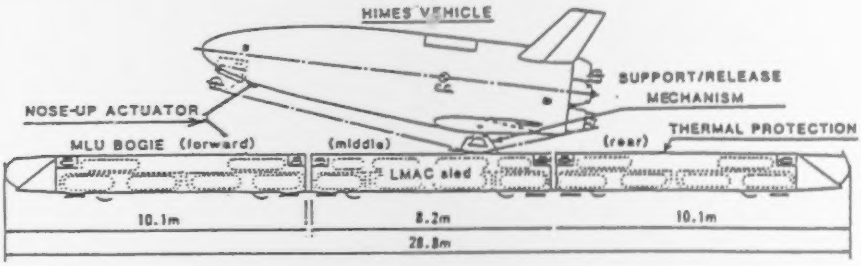


Fig. 12 The HIMES/LMATO launch system
HIMES; Highly Maneuverable Experimental Space (Vehicle)
LMATO; Linear Motor Assisted Take-Off

This vehicle would be initially accelerated to 250 km/h by linear motors alone. Rockets would then be fired to assist the linear motors in accelerating to 500 km/h. During this time, vehicle systems would be checked, and if no problems were found and everything was OK, the locks would be released and the space vehicle would take off at

500 km/h. If any problem was found during the checks, the rockets would be stopped and the vehicle would be braked using the linear motors, thereby avoiding any major damage. This system would incorporate subsystems already shown to be technologically feasible, and the vehicle is therefore presently considered viable. I am confident that launching a space vehicle as shown in Fig. 13 is no longer a dream.

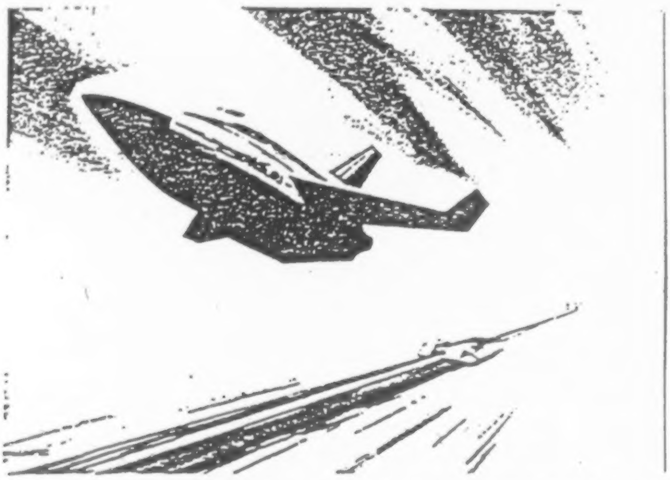


Fig. 13 Artist's concept of sled-assisted horizontal take-off of a space launch vehicle

Conclusion

Applications for superconductivity can be found not only in transportation, but in a wide range of other fields. To realize these many applications, I have proposed developing a "superconductivity town" as shown in Fig. 14. This town would provide facilities for research and development in applied superconductivity equipment and systems, as well as other facilities for durability studies. Realization of such a "superconductivity town" would also provide a place for international cooperation, and would, I am sure, lead to many valuable developments for mankind.

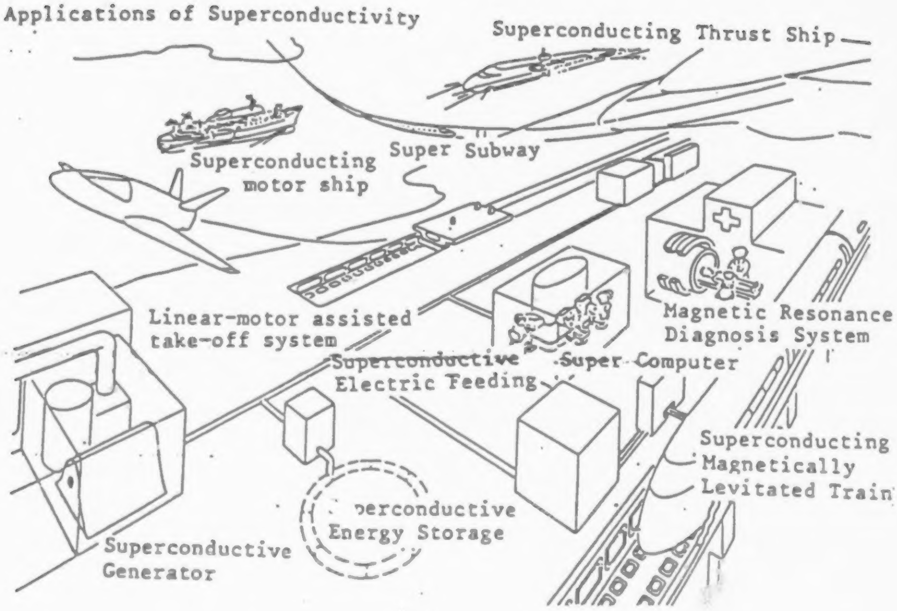

Applications of Superconductivity
Superconducting Thrust Ship
Superconducting motor ship
Super Subway
Linear-motor assisted take-off system
Superconductive Electric Feeding
Super Computer
Magnetic Resonance Diagnosis System
Superconducting Magnetically Levitated Train
perconductive Energy Storage
Superconductive Generator

Fig. 14 Future Applied Superconductivity Corridor

## REFERENCES

(1) K.Oshima, Y.Kyotani, "The Japanese magnetically suspended train project", Proc. 4th International Cryogenic Engineering Conf., Eindhoven (May 1972)

(2) Y.Kyotani, "Development of superconducting levitation trains in Japan", Proc. ICEC5, Kyoto, May 1974, CRYOGENICS 15, 372 (July 1975)

(3) T.Ohtsuka, Y.Kyotani, IEEE Transaction on Magnetics, vol. MAG-11, No.2, 608 (1975)

(4) T.Ohtsuka, Y.Kyotani, IEEE Transaction on Magnetics, vol. MAG-15, No.6, 1416 (1979)

(5) Y.Kyotani; "Development of electrodynamically suspended transport system in Japan", Proc. International Symposium on Traffic and Transportation Technologies, 31, Hamburg (June 1979)

(6) T.Ohtsuka, Y.Kyotani, "Recent progress in superconducting magnetic levitation tests in Japan", IAS Conf. Record, 328 (September 1980)

(7) Y.Kyotani, "Running tests on superconducting magnetic levitation system", CONVERGENCE 80, Dearborn (September 1980)

(8) Y.Kyotani, "Present status of research and development of superconducting magnetic levitation railway-research on linear motor magnetic levitated system in the Japanese National Railways", RAIL INTERNATIONAL, 156 (April 1981)

(9) Y.Kyotani, Proc. [illegible]EC 9,1, Kobe (1982)

(10) T.Ohtsuka, Y.Kyotani, "Recent progress on superconducting magnetic levitation in Japan", Proc. ICEC 10 (1984)

(11) Y.Kyotani, "MAGNETIC TRANSPORT SYSTEM DEVELOPMENT IN JAPAN", MT-9, Zurich (1985)

(12) Y.Kyotani, H.Tanaka, "PRESENT STATUS OF JNR MAGLEV DEVELOPMENT", Proc. International Conference on MAGLEV & LINEAR DRIVES, Vancouver (1986)

(13) M.Nagatomo, Y.Kyotani, "FEASIBILITY STUDY ON LINEAR-MOTOR-ASSISTED TAKE-OFF (LMATO) OF WINGED LAUNCH VEHICLE", IAF '86, Innsbruck (1986)

(14) Y.Kyotani, "SUPERCONDUCTIVE DRIVING VEHICLES", CHEMRAWN VI, Tokyo (1987)

(15) Y.Kyotani, "RECENT PROGRESS BY JNR ON MAGLEV", MT10, Boston (1987)

# Maglev Approaches toward Practical Use

*Hisashi TANAKA*
*Senior Chief Researcher*
*Maglev Project*
*Railway Technical Research Institute*

## 1. Introduction

As introduced occasionally in this journal, the Japanese National Railways, now restructured as the "Japan Railways Group", has been engaged in a development of magnetically levitated trains utilizing superconducting magnets.

Because liquid helium is essential to operate the superconducting magnets for the time being, realization of the maglev trains is considered to be very hard. Further, such development is criticized sometimes to be time-consuming due to its tackling difficult problems. However, this development plan has originated based on an idea that a means of land transportation for the next generation needs to be as fast as 500 km/h in the maximum speed. To actualize this speed, a superconducting magnet system with greater height of levitation (around 100 mm) and complete non-contact of vehicles and guideways are required.

The JNR has commenced the development of such superconducting magnet system in 1970. At that time, there were no technological accumulation and achievement on the superconducting magnets for rolling stock use as well as the electro-dynamic suspension system (EDS). Accordingly, the development work was forced to proceed step by step taking a long period of time up to the present, from theoretical analysis and fundamental experiments, running test at low speed on the premises of the Railway Technical Research Institute, to construction of Miyazaki test track followed by high speed running test on the track. In December, 1979, satisfactory operation at speeds up to 517 km/h, which was higher than the target speed, was confirmed with an experimental vehicle, ML500. Since 1980, results of such tests with MLU001 experimental vehicles (Photo 1) as multiple-unit operation, manned operation, and operation on a guideway with irregularities have met our expectations. Thus, we have finally reached a manufacturing stage of a prototype vehicle which is one generation before those for revenue service.

In this article, new cycloconverters put into operation in December, 1986, and the novel prototype vehicle completed in March, 1987, are introduced. In addition, a program for realizing our maglev transport system is referred.

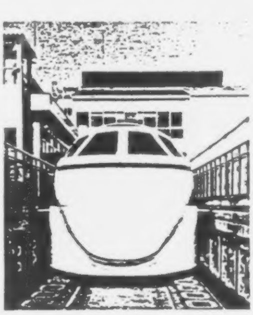


Photo 1 Experimental maglev vehicle, MLU001

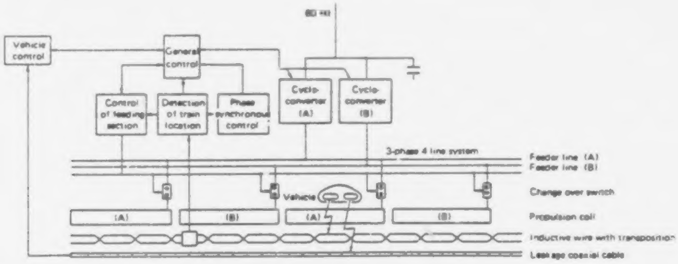

60 Hz
Vehicle control
General control
Control of feeding section
Detection of train location
Phase synchronous control
Cyclo-converter (A)
Cyclo-converter (B)
3-phase 4 line system
Feeder line (A)
Feeder line (B)
Change over switch
Vehicle
(A)
(B)
(A)
(B)
Propulsion coil
Inductive wire with transposition
Leakage coaxial cable

Fig. 1 Electric power supply system of the Miyazaki Test Track

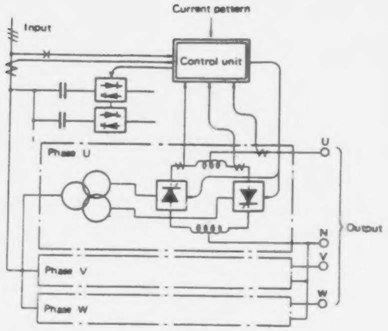


Fig. 2 System configuration of circulating current type converter

## 2. Circulating current type cycloconverter

Variable amplitude and variable frequency alternating current to actuate the coils for propulsion and guidance is supplied through cycloconverters installed in the substation. In the case of the Miyazaki test track, a range of frequency is 0 to 34 Hz corresponding to a train speed range of 0 to 500 km/h. As an output frequency of a conventional cycloconverter is limited to about 1/3 of its input frequency, 60 Hz three phase a.c. received is once converted to 120 Hz through a motor-generator and then fed to the cycloconverter. Though such MG system is superior in terms of the capacity of absorbing reactive power and higher harmonics, its size is large and its weight is as heavy as 140 tons for a unit composed of motor of 10 MW and generator of 25 MVA, and accordingly, its maintenance work was not so easy. An electric power supply system newly developed to solve the above problem is called circulating current type cycloconverter. It enabled direct reception of electric power without motor-generator because the output frequency can be improved up to about 2/3 of the input frequency. (Fig. 1)

The composition of the circulating current type cycloconverter is shown in Fig. 2. A pair of two converters for each phase are inversely connected in parallel for suppressing ripple current, and the neutral point of the reactor is connected to the linear synchronous motor load. And these two converters are isolated mutually by input transformer. Each converter is composed of 24 pulse converters in which 4 stage cascade-connected 6 pulse converters are included. On the input side of the cycloconverter, condensers are connected through thyristor switches.

A pattern of an electric current to be fed to the coils for propulsion and guidance is given to a controller. Output voltage of the two pairs of converters is controlled so that the generated currents can show an identical a.c. waveform with this pattern. The controller turns the thyristor switches on or off according to the value of the output current, and connects the condenser of necessary capacity to the input side. And thus, the circulating current flowing between the two converters is regulated so as to make overall reactive power null by cancelling out capacitive component of the reactive power generated by the condenser and inductive component of the reactive power produced by the cycloconverter. Although large capacity condensers and filters are required as countermeasures for reactive power and higher harmonics respectively, the circulating current type cycloconverter generates better waveform than the non-sine curve produced by the conventional noncirculating current type cycloconverter for the reason of providing a period for suspension of current supply necessary for the latter.

The former electrical facilities was designed for feeding one unit of ML500 experimental vehicle and its capacity was only 10 MVA (this capacity is rather large as compared with the existing lines for commercial service because higher acceleration and retardation are required for short test track). As a result, the maximum speed of the trains composed of MLU001 vehicles were limited to 305 km/h and 222 km/h for 2- and 3-vehicle trains respectively. The capacity of the new cycloconverter is raised up to 16 MVA, and accordingly, 352 km/h in running speed for a three vehicle train was recorded in December, 1986, followed by marking of 400.8 km/h for a manned two vehicle train in February, 1987.

## 3. Prototype vehicle

### (1) Outline

To complete past accomplishment of technological development as well as to clearly express the image of the maglev system at its final stage of development, and to ultimately confirm its safety, reliability, and practicability, a prototype vehicle, MLU002 was manufactured recently. As the MLU002 is intended to be tested on the Miyazaki test track, it is constructed to fit to the existing guideway of the test track. However, basing on the results of demonstration run at the Miyazaki test track, furnishing design, criteria and so forth will made possible for promoting application projects of the system now under plan in Japan.

Main features and general appearance of the MLU002

Table 1 Main features of MLU002

| | |
|---|---|
| Vehicle dimension | |
| Length x Width x Height | 22.0 m x 3.0 m x 3.7 m |
| Seating capacity | 44 |
| Mass | 17 t |
| Superconducting coil | |
| Number of coils | 3 poles x 2 bogies x 2 rows |
| Magnetomotive force | 700 kA |
| Pole pitch | 2100 mm |
| Suspension | |
| Lift | [illegible] kN |
| Effective gap | 110 mm |
| Guidance | |
| Guidance force | 83.3 kN at 50 mm shift |
| Effective gap | More than 150 mm |
| Propulsion | |
| Thrust | 0 – 79.4 kN |
| Phase | 3 |
| Frequency | 0 – 28 Hz |
| Voltage | 5800 V |
| Current | 900 A |
| Maximum speed | 420 km/h |

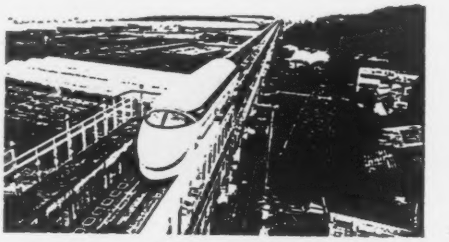


Photo 2 Prototype maglev vehicle, MLU002

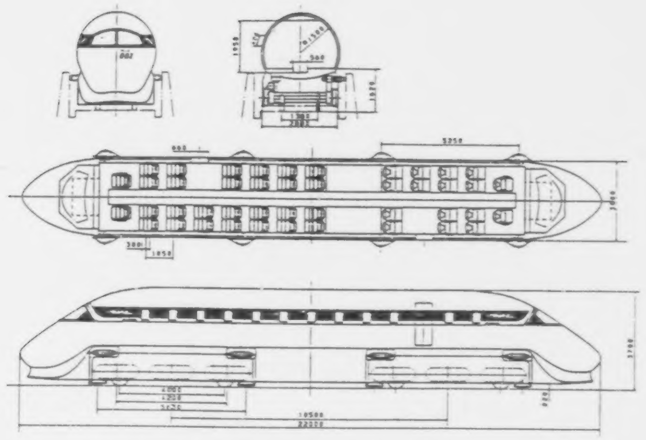


Fig. 3 Prototype maglev vehicle, MLU002

vehicle are shown in Table 1, Photo 2 and Fig. 3, respectively. The overall length of the MLU002 vehicle is 22 m which is about two times as large as the previous MLU001, and almost equal to a vehicle for commercial use. The superconducting magnets for the MLU001 were arranged continuously in longitudinal direction of the vehicle. The number of these magnets for the MLU002 are reduced reflecting the enhanced performance of the magnets, and they are only disposed on the bogie portion like conventional rolling stock with bogies. Reduction in the number of magnets is effective in reducing overall weight of the vehicle, improving the mass ratio of vehicle body to bogie which affects riding quality, and cutting down operating cost.

As the MLU002 vehicle is planned to be manufactured only one in number, both ends of the vehicle are streamlined, and its seating capacity for passengers is limited to 44 because measuring instruments are to be installed on the floor of its passenger room. However, when it is converted into revenue service model, plural number of such vehicles will be coupled together to form a train set, and they will have enough accommodations for as many as 70 to 80 passengers per vehicle. Though its maximum speed is designed to be 500 km/h, actual operating speed on the test track will be lowered to about 420 km/h because the vehicle has to be operated leaving ample distance at the end of the short test track of 7 km in overall length, and such a high retardation as allowed for the unmanned experimental vehicle, ML500, can not be applied to the empirical vehicle for manned travel.

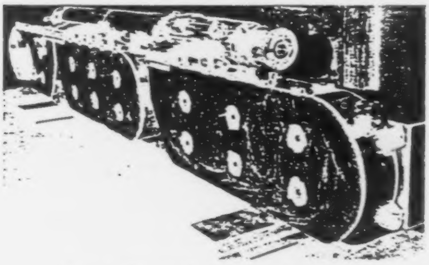


Photo 3 Superconducting magnet for MLU002

(2) Superconducting magnet

The MLU001 has proven that the superconducting magnet for rolling stock use with built-in refrigerator (cold box compartment) has almost reached the stage of completion by its light weight, compactness in size, slightness in heat intrusion. High degree of its reliability has also been attested. As regards the coils of the MLU001, there are two types, one of which is two coil type (provided with two superconducting coils) and another is single coil type. As for the MLU002, its coils are three coil type that is the largest type to date as shown in Photo 3. In addition, the following outcomes of development have been incorporated in the MLU002 vehicle.

Though wires made of niobium-titanium alloy series are used for the superconducting coil as before, copper ratio of the coil (ratio of cross-sectional area of copper to that of the superconductor) was lowered from 2 to 1 so as to reduce coil weight all the more. Further, excitation and demagnetization performance of the coil has been improved, thereby enabling the coil to excite or to demagnetize within one minute or so. As a result of these improvements, working hours at a depot has been shortened considerably, heat intrusion from outside through power leads has been decreased, and thus, development of superconducting coils that will not be necessary for depending on the depot during commercial operation in future has been expected.

As to the on-board refrigerators, one operated by the Claude cycle as well as another run by the reversed Stirling cycle combined with the Joule Thomson (JT) loop were already adopted by MLU001. For the MLU002, a complete Stirling cycle without the JT loop is applied for the first time to its refrigerator reflecting the results of the study entrusted by the Science and Technology Agency. A comparative test of the complete Stirling cycle and the Claude cycle will be conducted by mounting one refrigerator on one bogie and another one on the other bogie. The Stirling cycle is superior to other systems because of higher efficiency and simpler maintenance work due to the absence of valve mechanism.

### (3) Vehicle body and bogie, etc.

The MLU001 vehicle was manufactured mainly for experimenting magnetic levitation performance. While in the MLU002, many considerations are incorporated to reduce air resistance, aerodynamic instability and noise, i.e. to apply the most appropriate vehicle body configuration selected by wind-tunnel tests, etc., to make the surface of the vehicle as smooth as possible (elimination of a difference in surface plates around the window, change of jointing method of the vehicle body from rivetting to welding, etc.), to house auxiliary supporting wheels completely during levitation, to attach covers to auxiliary guide wheels, to make the vehicle body airtight, and so forth. The middle part of the vehicle body is made of aluminium alloy, whereas both ends of the body (5 m in length) composed of many curved surfaces are of CFRP. Air springs, vibration dampers and anchors are provided between the vehicle body and the bogies. An emergency landing device (sliding shoes) are fitted to the four corners of each bogie to back the supporting wheels up when their tires burst. These devices function as mechanical brake as well by frictionally sliding against the guideway when the electric brake fails.

In addition to lighting and air conditioning, information panels for passengers and so on are furnished as passenger accommodation. Seat belts are provided for every passenger as acceleration and retardation of the vehicle is rather high. Based on the test results obtained already, electric power necessary for operating the on-board equipment including the refrigerator is estimated to be approximately 40 kW per vehicle, and it is positively foreseeable that the power of this amount may be fully collected through noncontact collection at speeds not less than 160 km/h. Nevertheless, the MLU002 is fed by batteries like the MLU001 because the Miyazaki test track is too short to secure enough time for power collection.

## 4. Passenger transportation plan by maglev system

Though running test of the MLU002 prototype vehicle is planned tentatively to take place for a period of two years, it is considered that one year would be long enough to virtually confirm its performance and feasibility.

A preoccupation that the superconducting magnet system requires large-scale facilities has contributed to the fact that the target of application of such system has been confined up to this date to sections with long distance and mass traffic like the section between Tokyo and Osaka. However, repetition of running test on the Miyazaki test track, which is as short as 7 km in length, has resulted in confirmation of a belief that the system will also be applicable to shorter sections, roughly 30 to 50 km in length, as an access to the airport. When a distance between two stations is 30 km or so, then a scheduled speed for this section will be more than 300 km/h which would have a significance for the adoption of this system.

As for a practical maglev system, two types are being contemplated, i.e. one for short distance service and another for long distance operation, though there exists no substantial difference between them.

### (1) Maglev system for short distance service

For the active track system, a train and a substation correspond to one to one. And one substation can cover about 50 km long section. As the maximum vehicle speed is set at 500 km/h, both ends of the section can be linked in 7 to 8 minutes, and thus, a headway of 20 minutes or so can be secured even for a single track. Accordingly, such track as above is capable of providing shuttle service with only one train and merely one substation. Supposing a train composed of five or six vehicles (with a seating capacity for about 400 passengers) is to be operated, such coils of 6,000 to 7,000 V class as those being used at the Miyazaki test track would be utilized as the coils to be laid down on the ground for the above rather short track. If the number of trains is increased so far as 3 and a train stays at each of the terminals while the third train is in operation, then the headway of the trains will be shortened still more. As branching-off the trains at both terminals and the like, where trains will stop inevitably, will be carried out in the running mode using supporting wheels, simple switch may be utilized such as those already being applied to the new transportation systems with rubber tired vehicles. That is to say, the system for short distance service will reach a level of commencing construction of the system for revenue service one or two years after the completion of proof test by the prototype vehicle, MLU002. Obviously, extension of this system by placing stations at intervals of 30 to 50 km is practicable. (Fig. 4)

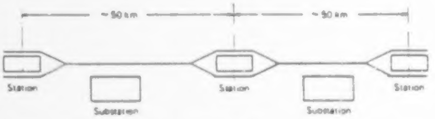


Fig. 4 Short distance line of maglev system

### (2) Maglev system for long distance service

The followings are needed to build this system for long distance service, i.e. transient control between substations when a train passes through a boundary of adjacent substations located at an interval of about 50 km, switches to be placed at the intermediate stations and capable of letting a nonstop train to pass at its maximum speed, ground coils which can withstand high voltage necessary for operating long and heavy trains and so forth. To cope with these problems, various simulations, basic experiments, and partial manufacture for trial, etc. are being under way. All of these problems are considered to be soluble within 2 to 3 years because no serious matters to be overcome are foreseen.

When the system for long distance service is to be constructed, a section of 40 to 50 km in length will be preferentially completed as a model line like Kamonomiya district and Oyama district for the Tokaido Shinkansen and the Tohoku Shinkansen respectively, and comprehensive tests including such final confirmation as high speed passing-by of two trains and high speed running of train through tunnel will be carried out.

## 5. Outline of maglev vehicle for commercial service

As regards the arrangement of the superconducting coils in running direction of vehicle, a continuous disposition was tested by the MLU001 experimental vehicle and an intermittent arrangement (called centralized arrangement) by the MLU002 prototype vehicle. Though both of these arrangements have been confirmed in application to commercial vehicles, a new centralized arrangement of the superconducting magnets based on still more advanced concept is being considered for application to the vehicle for commercial service. Under this new arrangement, the magnets will be provided only at both ends of the vehicle and the vehicle will be of articulated type. (Fig. 5 and

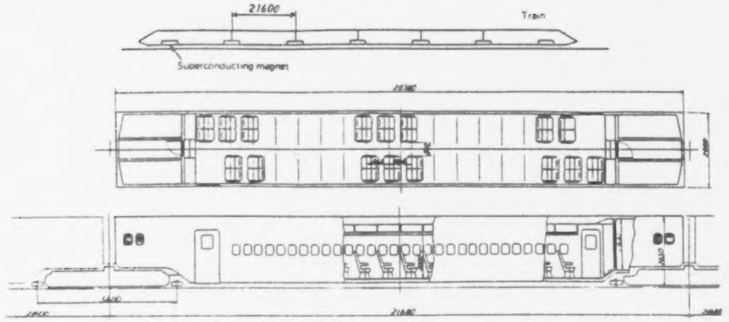


Fig. 5 Maglev vehicle for commercial service

Table 2) This type of vehicle will produce less air resistance because of its smaller sectional area resulted from reduced vehicle height which will be realized by lowering the floor height of passenger room that may be placed between two bogies. In addition, as the passenger room will be located apart from the superconducting magnets, magnetic flux density in the room will be reduced considerably, and accordingly, provision of magnetic shielding only for gangway above the magnet, and machine rooms will be required. The pitch of the superconducting coils for the vehicle of revenue service will be extended from that of the Miyazaki test track in order to cut construction cost by decreasing the number of ground coils. Regarding the ground coil itself, simplification of its installation work, buring it in concrete wall of the guideway for smoothing guideway surface are being contemplated and some partial tests are already under way. (Photo 4)

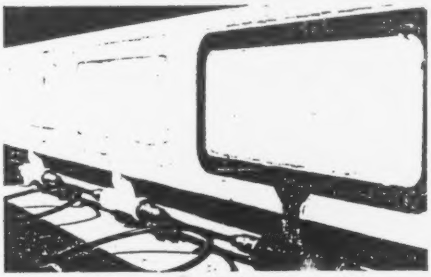


Photo 4 Ground coils buried in cc -te slab

## 6. Conclusion

Recently, materials of ceramics that turn into superconducting state without the use of liquid helium are being discovered in succession. Already at the time when the Japanese National Railways set about development of the superconducting maglev system, there was a view that superconducting at normal temperature would be practicable. However, the JNR has proceeded with the development using materials that require liquid helium for the time being, because the time of discovery of a new material was uncertain and once such a new material is discovered, then the realization of the maglev system would become much easier. Though at the present time, wires of ceramics are still low in current density and are very hard to be bent to form coils, once these drawbacks are improved, they will, of course, take the place of the present material. And the compact helium refrigerator that has been developed under this project will also be very useful for other purposes.

Table 2 Design specifications of a maglev system for commercial service

| | |
|---|---|
| Maximum speed | 500 km/h |
| Vehicle | |
| Length × Width × Height | 28.0 m × 2.8 m × 2.65 m (End car)<br>21.6 m × 2.8 m × 2.65 m (Mid car) |
| Mass | 27 t (End car) 18 t (Mid car) |
| Seating capacity | 67 (End car) 68 (Mid car) |
| Train | |
| Number of vehicles | 14 |
| Length | 315 m |
| Mass | 270 t |
| Seating capacity | 950 |
| Superconducting coil | |
| Length × Width, Pole pitch | 2.2 m × 0.5 m, 2.7 m |
| Magnetomotive force | 700 kA |
| Number of coils per bogie | 4 (2 poles × 2 rows) |
| Ground coil for suspension | |
| Length × Width, Pitch | 0.6 m × 0.3 m, 0.9 m |
| Ground coil for propulsion and guidance | |
| Length × Width, Pitch | 1.5 m × 0.6 m, 1.8 m |
| Voltage | 19 kV a.c. |
| Levitation height | 100 mm |
| Midway between tracks | 5.4 m |
| Curve radius | over 6000 m at 500 km/h |
| Gradient | 100 ‰ (maximum), 60 ‰ (continuous) |

A demonstration using the MLU002 prototype vehicle is considered to be very important to promote public understanding that the development of the maglev system has advanced remarkably thus far, since some people are taking a view that the superconducting maglev system is not a proven technology yet and planning of a specific project is a matter of the distant future.

In Japan, development of a ship propelled by superconducting magnets without screw propellers has commenced, and a space shuttle project of Japanese version is disclosed in which a winged rocket will be launched from a magnetically levitated sleigh. A dream of running maglev trains through vacuum tube type intercontinental undersea tunnel may come true in the future.

After restructuring of the JNR, effective April 1, 1987, the development of the maglev system was transferred to a newly organized foundation, Railway Technical Research Institute for continuous and expeditious promotion.

We sincerely hope that our studies will accomplish as a novel transportation means worthy of coming new era.

# SUPERCONDUCTIVE DRIVING VEHICLES

Y. Kyotani

Abstract - The commercial application of superconductive driving vehicles for use in intercity passenger transportation is now imminent. Developed by Japan National Railways, the ML500 experimental vehicle, measuring 10 meters in length and weighing 10 tons, achieved a maximum speed of 517 km/h in December, 1979. This was followed by the manned operation at 400 km/h of a two-car train, the MLU001 in February, 1987, and then by the unveiling of the 22-meter long, 17-ton MLU002 prototype at the Miyazaki Test Center in March, 1987.

All of the experimental vehicles have thus far shown stable performance. Experimental results of a three-car train have shown that both travel stability and riding comfort improve with increasing number of cars in the train. In addition, aberrations were purposely introduced to the guideway and coils installed on the guideway in order to compile data for future design, construction, and maintenance.

This railway has already attracted attention both here in Japan and from around the world, and, as each experiment is concluded successfully, the call for the construction of an operating line has greatly increased. This success can be attributed both to the progress made in research and development, and to the weight reduction advances in superconducting magnets and a wide variety of other components, achieved through the innovative use of new technologies and new materials.

Although this mode of transportation is a relatively young one, it possesses great potential for future development as well as a variety of technological spin-offs, including the further development of new materials.

## INTRODUCTION

Superconductive driving vehicles (SCDV) make use of superconducting magnets for linear synchronous motor (LSM) propulsion and electrodynamic magnetic levitation.

JNR began research and development on superconductive driving vehicles in 1970. In December, 1979, the ML500 unmanned experimental vehicle, measuring 13.5 meters in length and weighing 10 tons, achieved a maximum speed of 517 km/h. In September, 1982, manned operation began of a two-car train, the MLU001 measuring 10 meters in length and weighing 10 tons. This was followed by the manned operation of a three-car train in November of the same year, and then by the manned operation of a two-car train at a maximum speed of 400 km/h in February, 1987. Finally, the 22-meter long, 17-ton MLU002 prototype was unveiled in March, 1987.

A leading role in the achievement of these successes was played by advanced materials. Following a basic explanation of the SCDV, we will discuss the role that these advanced materials played in its development.

## SCDV

The SCDV derives its propulsion from the attraction and repulsion properties of magnets. A south polarity on the guideway applied to the north polarity magnets at the front of the SCDV causes the vehicle to move forward. Additional propulsion is achieved by applying a north polarity to the north polarity magnets mounted on the rear of the SCDV.

Thus, in order to have the vehicle move forward continuously, the polarities of the magnets arrayed on the guideway simply have to be changed in accordance with the speed of the vehicle. This is done by arranging conductor coils on the guideway and supplying a synchronous alternating current which changes direction in accordance with the position of the vehicle. This type of electric motor is called a linear synchronous motor (LSM). There are two types of LSMs, air-core and iron-core. On the SCDV, SCMs are used on the vehicle, while air-core LSMs with hollow-core aluminum coils are used on the guideway.

Conductive coils or sheets are arranged on the guideway. When the vehicle passes over these coils or sheets, an induced current flows to the coils or sheets and the vehicle is levitated by the electromagnetic force generated by this current and the magnetic field of the on-board magnets. This method of levitation is called ED (electrodynamic), and when SCMs are used for the on-board magnets, the method is referred to as superconductive magnetic levitation.

The LSMs and ED magnetic levitation which we have been discussing both require magnets to be mounted onto the vehicle. These magnets must be lightweight, compact, and have a low power consumption. For this reason, the SCMs are used in the persistent current mode. By using SCMs as the on-board magnets, clearance of 10 cm or more can be easily obtained during levitation. The LSMs are also capable of sufficient performance at clearances of more than 10 centimeters.

The special features of an SCDV railway as a means of transportation are that speeds in excess of 500 km/h are possible even on steep gradients, there is no pollution, and construction, operation, and maintenance are all relatively simple.

## RESEARCH AND DEVELOPMENT HISTORY AND MATERIALS

Japan National Railways began research on linear electric motors in the early 1960's, and, as the result of research on intercity passenger transportation beginning in 1968, it was concluded that large-scale research and development was needed, and that the SCDV held the most promise for future development.

In 1970 a basic ED magnetic levitation experimental device using an SCM was built. In addition to helping in the development of low-temperature and superconduction technology, this also served to provide data concerning ED magnetic levitation. In 1972, an ED magnetic levitation LSM propulsion device (LSM200) was constructed for experimental purposes. Because levitated travel requires a lightweight SCM, titanium was used for the spools of the SC coils. The ML100 test vehicle using ED magnetic levitation and linear induction motor propulsion was completed and tested in the same year. In both cases the levitation travel was successful. Research was also begun on a lightweight SCM cryostat in order to develop a lightweight, compact SCM which had little heat penetration.

The SC coil is installed inside the SCM cryostat and is immersed in liquid helium. The cryostat consists of a helium vessel (inner vessel) and an outer vessel. The space between these two vessels is maintained in a vacuum state and contains a multi-layer insulator and a thermal shield.

The thermally insulated supporting material used to transmit the force generated by the lightweight SC coil to the outside is also an important factor in lightweight construction. In 1972 and 1973, using research prototypes of the lightweight cryostat in addition to studies of shape and structure, a wide range of materials were subjected to testing, including stainless steel, aluminum, aluminum alloy, titanium, titanium alloy, and composites.

In 1975, an ED magnetic levitation LSM propulsion test vehicle (ML100A) using an advanced SCM was completed and tested. This was the first time SC coils and ground coils were used simultaneously for propulsion and guidance.

In 1977, experiments were begun with the 13.5-meter long, 10-ton ML500 unmanned experimental vehicle using the Miyazaki test track. On the ML500, not only had the weight of the SCM been reduced even further, but the weight of the entire vehicle as well. The vehicle body and the frame were constructed primarily of aluminum alloy. CFRP was used for parts such as the data transmission antenna mounting.

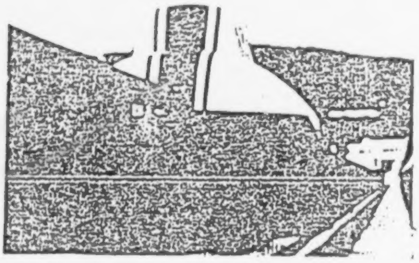
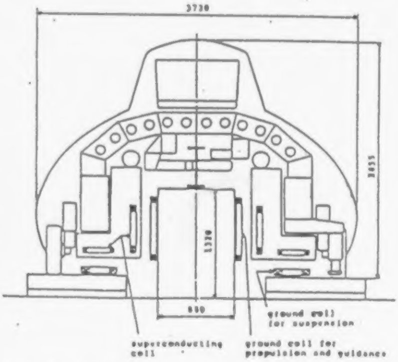
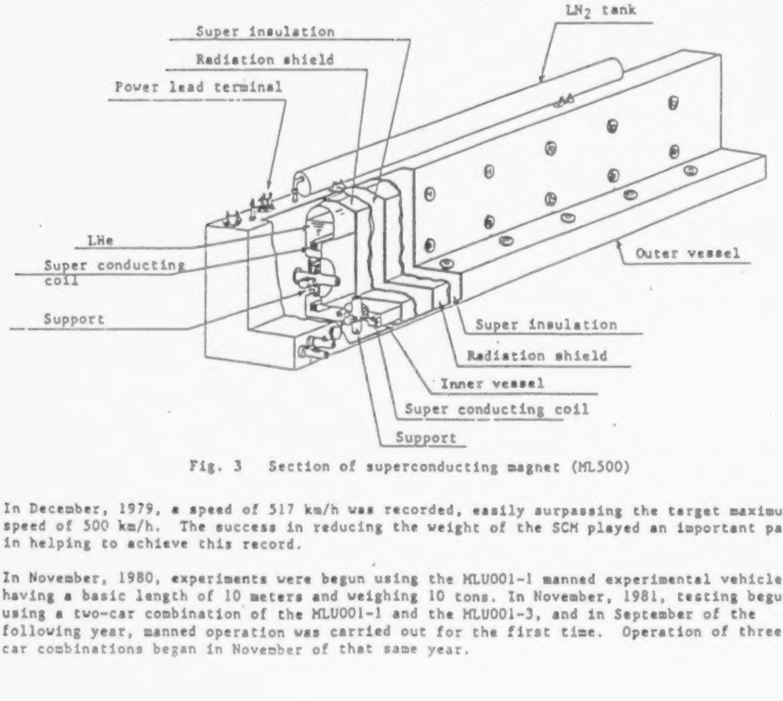


Fig. 1 ML500


3730
2835
1370
850
ground coil for suspension
superconducting coil
ground coil for propulsion and guidance
Fig. 2 Cross section of inverted T-shaped guideway and vehicle (ML500)


LN$_2$ tank
Super insulation
Radiation shield
Power lead terminal
LHe
Super conducting coil
Support
Outer vessel
Super insulation
Radiation shield
Inner vessel
Super conducting coil
Support
Fig. 3 Section of superconducting magnet (ML500)

In December, 1979, a speed of 517 km/h was recorded, easily surpassing the target maximum speed of 500 km/h. The success in reducing the weight of the SCM played an important part in helping to achieve this record.

In November, 1980, experiments were begun using the MLU001-1 manned experimental vehicle having a basic length of 10 meters and weighing 10 tons. In November, 1981, testing begun using a two-car combination of the MLU001-1 and the MLU001-3, and in September of the following year, manned operation was carried out for the first time. Operation of three-car combinations began in November of that same year.

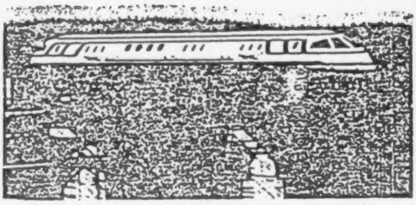


Fig. 4 MLU001 three-unit train

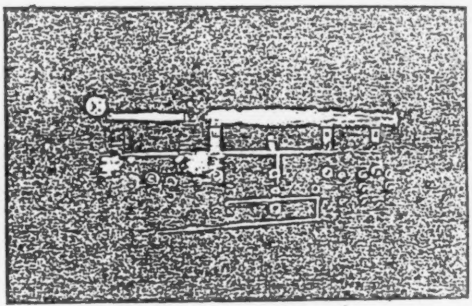
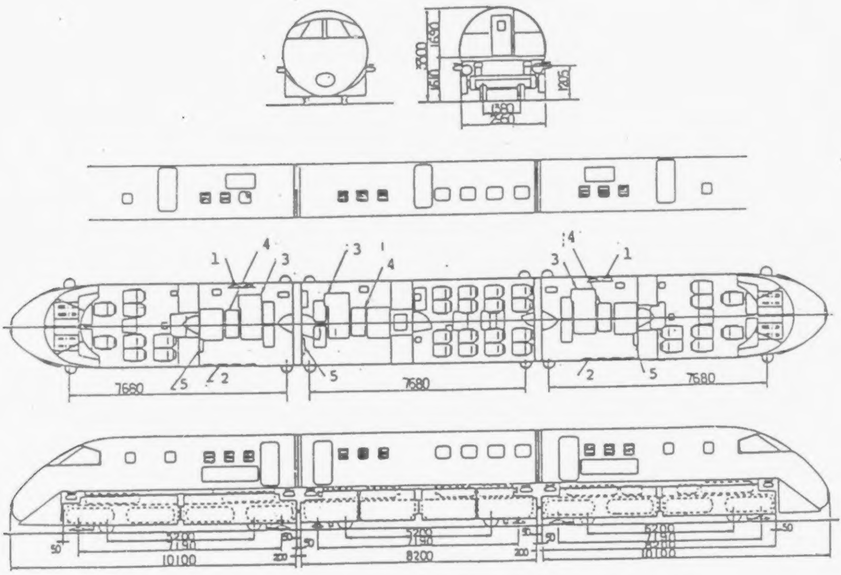


Fig. 6 Superconducting magnet and refrigerator (MLU001-3)



3300
1690
1610
1205
1580
2580
1
4
3
3
1
4
4
3
1
5
2
5
2
5
7680
7680
7680
50
5200
7190
10100
200
50
5200
7190
8200
200
50
5200
7190
10100
50

Fig. 5 Outline of the connected MLU001-1, 2 and 3 test vehicles

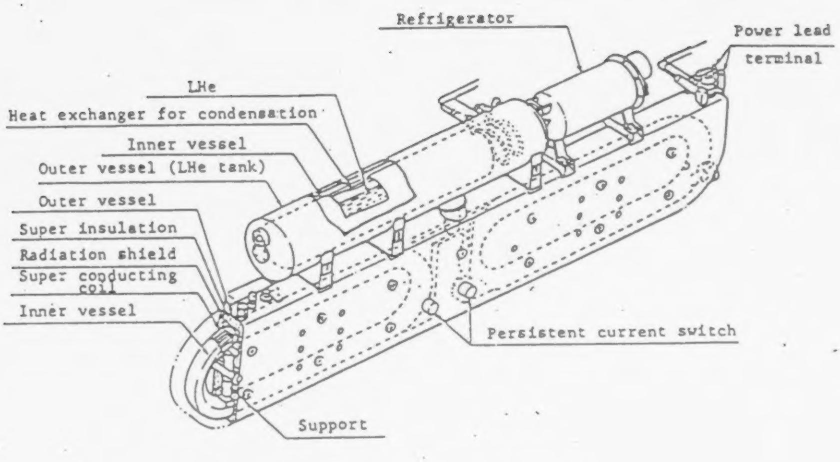
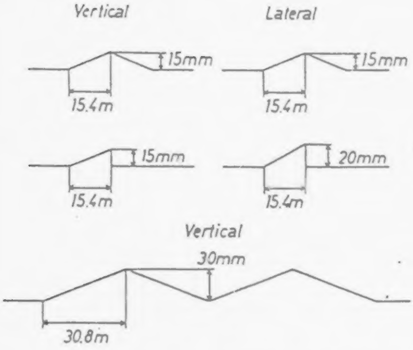

Refrigerator
Power lead terminal
LHe
Heat exchanger for condensation
Inner vessel
Outer vessel (LHe tank)
Outer vessel
Super insulation
Radiation shield
Super conducting coil
Inner vessel
Persistent current switch
Support

Fig. 7 Outline of superconducting magnet (MLU001-3)

The maximum speeds prior to increasing the capacity of the power supply equipment in 1986 were 400 km/h for a single car, 305 km/h for a two-car combination, and 220 km/h for a three-car combination. In every case, levitation was accomplished smoothly and riding comfort was excellent. In comparisons at the same speed, vehicle motion became more stabilized with each increase in the number of cars. Riding comfort improved slightly as well.


Vertical
Lateral
15mm
15.4m
15mm
15.4m
15mm
15.4m
20mm
15.4m
Vertical
30mm
30.8m

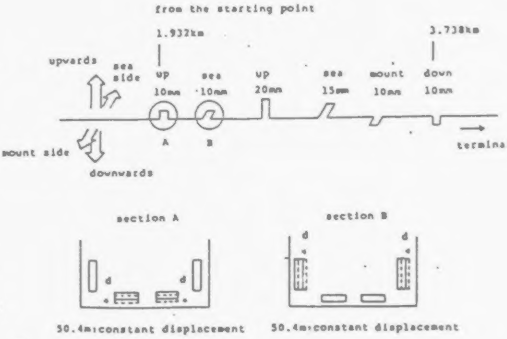

from the starting point
1.932km
3.738km
upwards
sea side
up 10mm
sea 10mm
up 20mm
sea 15mm
mount 10mm
down 10mm
A
B
mount side
downwards
termina
section A
d
d
section B
d
d
50.4m:constant displacement
50.4m:constant displacement

Fig. 8 Guideway irregularity test (example)

Fig. 9 Ground coil irregularity test (example)

Experiments were carried out in 1984 and 1985 in order to compile the data needed for design, construction, and maintenance when the time comes to put the system into actual operation. These experiments included travel tests with aberrations purposely introduced to the elevated beams, including height and alignment differences, and a series of two rises. Travel tests with aberrations included in the installation of the coils were also performed. In travel over a series of two rises, the magnitude of vibration used was adjusted to be close to the value calculated from the vehicle's natural vertical vibration and a maximum speed of 300 km/m. The height of the rise was 30 mm. When a two-car train was run on a guideway with these aberrations, the only change that occurred was a momentary decrease in clearance to 70 mm, normally 100 mm. It was confirmed during this test that the vibration damping characteristics of the SCDV are good.

The fact that aberration-resistant performance of a level never before possible in a railway was obtained is one of the significant characteristic features of this new railway system. And although the reasons behind this success include such factors as the ED magnetic levitation using SCMs and the use of LSM propulsion, another important contributing factor was the reduction of the weight of the vehicle. In order to achieve that, new materials were utilized on a scale which would never have been thought possible for conventional railways.

On February 4, 1987, the author and two other persons rode a two-car combination of the MLU001-1 and MLU001-3 in a travel test in which, through the installation of new power supply equipment, a maximum speed of 400 km/h was recorded. Because the length of the test track was only seven kilometers, acceleration was immediately followed by deceleration. Nevertheless, riding comfort was good, and because ED magnetic levitation was used, we were able to enjoy the beautiful scenery along the test track with no worries about support or guidance.

This experiment also provided confirmation that the new power supply equipment could be used for experiments with the next prototype, the MLU002. The MLU001-1 travelled a total of 42,300 kilometers in 9,200 experiments, but there was no damage to the vehicle or to the guideway coils.

The new materials used in the MLU001 and the Miyazaki test track included the following.

| | |
|---|---|
| Vehicle (MLU001) | |
| Rear vehicle body structure | CFRP |
| Carriage cover | Paper honeycomb |
| Body floor | Aluminum honeycomb |
| Signal lines between cars | Optical fiber cable |
| SCM | |
| SC wire | Nb-Ti/Cu |
| PCS | Nb-Ti/Cu x 30% Ni |
| Load support material | CFRP |
| Coil structure material | CFRP |
| Hermetic seals for power leads | Ceramic (alumina) |
| Helium refrigerator | |
| Regenerator (Stirling refrigerator) | Gd, Er, Rh |
| Ground coils | |
| Power station | Cycloconverter thyristor |
| Guideway sidewalls | High-manganese steel |

## MLU002

Based on successes achieved so far, the MLU002 was developed as a prototype to further progress towards practical commercial use. The MLU002 was unveiled at JNR's Miyazaki Test Center on March 28, 1987.

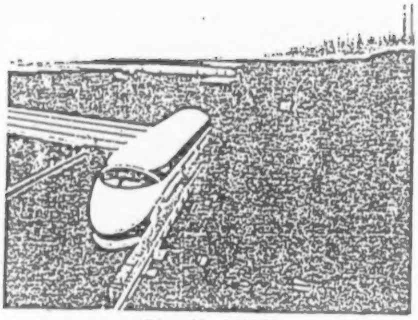
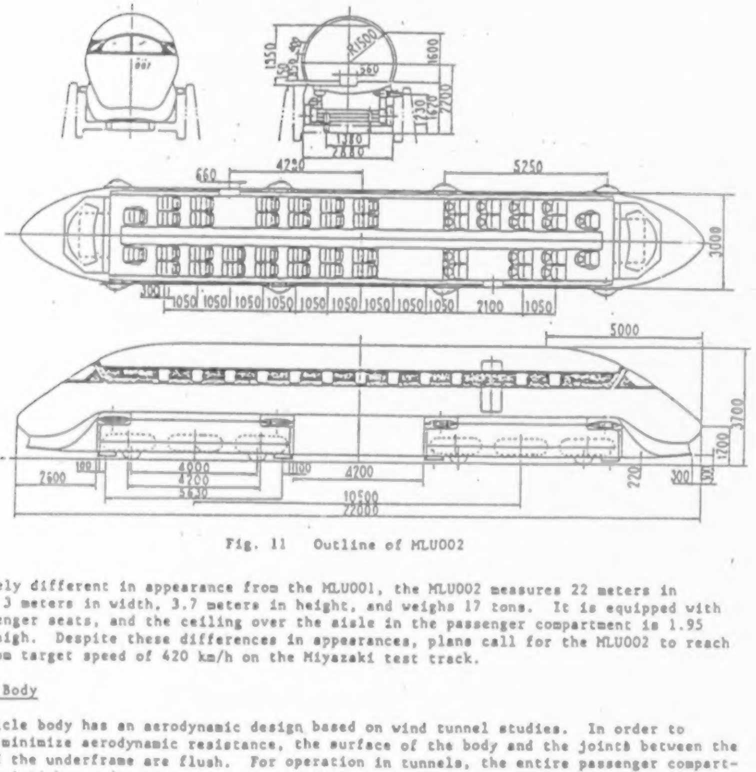


Fig. 10 MLU002



1350
R1500
1600
560
1230
1670
2200
1310
2880
660
4290
5250
3000
300
1050
1050
1050
1050
1050
1050
1050
1050
1050
2100
1050
5000
3700
1700
2600
100
4900
4200
5630
1100
4200
10500
22000
220
300

Fig. 11 Outline of MLU002

Completely different in appearance from the MLU001, the MLU002 measures 22 meters in length, 3 meters in width, 3.7 meters in height, and weighs 17 tons. It is equipped with 44 passenger seats, and the ceiling over the aisle in the passenger compartment is 1.95 meters high. Despite these differences in appearances, plans call for the MLU002 to reach a maximum target speed of 420 km/h on the Miyazaki test track.

Vehicle Body

The vehicle body has an aerodynamic design based on wind tunnel studies. In order to further minimize aerodynamic resistance, the surface of the body and the joints between the body and the underframe are flush. For operation in tunnels, the entire passenger compartment is airtight, and constructed of composite. Acrylic and reinforced glass is used for the front windows, and the side windows are a multi-layered construction.

36

# PRESENT STATUS OF JNR MAGLEV DEVELOPMENT

Yoshihiro Kyotani
Hisashi Tanaka

Technical Planning and Development Department
Japanese National Railways
1-6-5, Marunouchi, Chiyoda-ku
Tokyo 100, JAPAN

Abstract: This paper outlines planned improvements to the power supply for the JNR Miyazaki test track, to permit high speed operation of the coupled MLU001 test vehicle, describes a prototype vehicle which is to resemble a vehicle for commercial use, and discusses feasible time for introducing maglev service, safety of superconducting magnet performance, and other research.

## Introduction

Five years have passed since running tests of the MLU001 started at the Miyazaki Test Center. (Fig.1, Table 1) The first car of this set has been operated 7,503 times and its total running distance has reached 33,965 km.

The power supply equipment for the Miyazaki test track at present is adequate only for the single ML500 car, which recorded the record speed of 517 km/h on the inverted T-shape track. Maximum speed of a three car train is restricted to 222 km/h, and that of a two car train to 305 km/h.

In the present stage of testing, the following items have been considered so far [1],[2]

- Electromagnetic, aerodynamic, and vehicle dynamic characteristics with the U-type track structure
- On-board refrigerating system
- Ride quality
- Characteristics of the vehicle on various types of guideway with artificially introduced irregularities
- High speed running characteristics of a single vehicle (maximum speed 402 km/h)

Meanwhile, improvements to the equipment for power supply have been planned for carrying out running tests in the high speed range with coupled vehicles and completion of the equipment is expected in fiscal 1986.

In additon to this, a prototype single vehicle resembling a commercial-use vehicle will be manufactured in the same fiscal year.

I will comment on these developments and their achievement here.

Table 1 Main features of MLU001

| | |
|---|---|
| Vehicle dimension: Length x Width x Height | 10.1m x 3.3m x 3.0m (End Vehicle)<br>8.2m x 3.3m x 3.0m (Mid. Vehicle) |
| Mass | 10 t |
| Electrodynamic suspension | |
| Levitation force | 98 kN |
| Levitation height | 240 mm (between coils) |
| Effective gap | 100 mm |
| Null flux guidance | |
| Guidance force | 49 kN at 50 mm shift |
| Distance between coils | 355 mm |
| Effective gap | more than 150 mm |
| LSM propulsion | |
| Propulsion force | 51 kN |
| Phase | 3 |
| Frequency | 0-27 Hz |
| Voltage | 3,000 V |
| Current | 1,100 A |
| Brake force | |
| Regenerative | 51 kN |
| Generative | 25 kN |
| Mechanical | 8 kN |
| Maximum speed | |
| 3 vehicle train | 220 km/h |
| Single vehicle | 400 km/h |

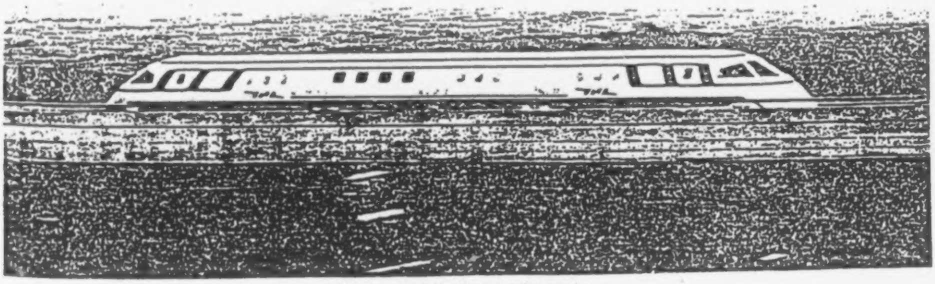


Fig. 1 MLU001 three-unit train

The front and rear of the body are constructed of CFRP. The center section is a semi-monocoque construction of aluminum alloy. The auxiliary power supply equipment room is located beneath the floor of the center section, and equipment rooms for the various control devices, measurement instruments, and communications equipment are located on either side of the central aisle.

Equipment in the passenger compartment includes air conditioning, data screens for information and, television, fire detectors, and various other items.

### Underframes

There are two underframes constructed of aluminum alloy for each vehicle body. Two air springs are provided at the center of each underframe. The low-temperature cooling equipment, superconducting magnets, auxiliary support and guidance devices and related components are installed on the underframes. The auxiliary support and guidance devices are constructed so that the tires can be retracted when the vehicle is levitated.

### Superconducting Magnets

Three superconducting coils with 700 kA of magnetic force each are installed on either side of each underframe, for a total of 12 superconducting coils per vehicle. As on the MLU001, each coil performs the three functions of propulsion, support, and guidance. Nb-Ti is used as the superconducting wire material, with a Cu ratio of one-to-one in order to reduce the weight.

### Low-temperature Cooling Equipment

The vehicle is equipped with an on-board helium liquifier-refrigerator. Indirect cooling is normally performed using the heat exchanger installed inside the cryostat, and, when necessary, can also be performed by a reliquifier. The cycles used are the Claude cycle and the Stirling cycle. The Stirling cycle is being researched by JNR at the request of the Science and Technology Agency. The Stirling cycle is capable of reaching a level of 4 K.

## CONCLUSION

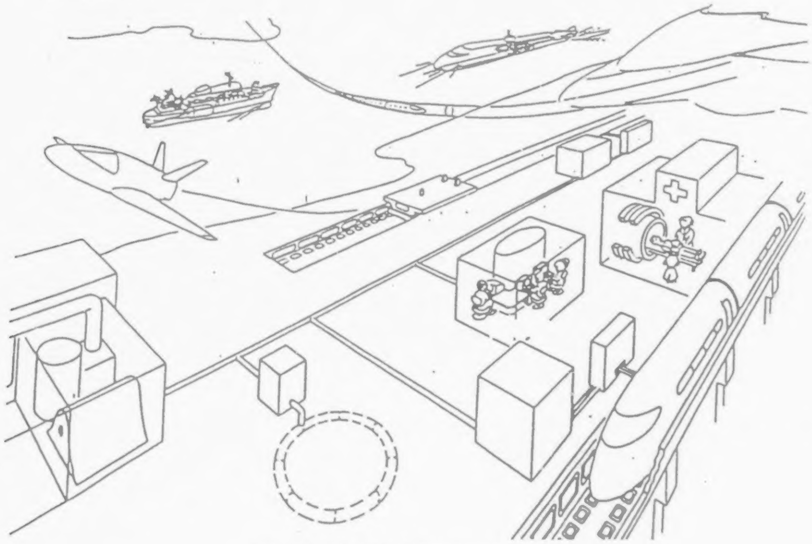


Fig. 12 Future city-applied super

Research and development of the SCDV has progressed rapidly in all areas, with substantial support in the area of materials. The MLU002 should go into actual operation soon on short-distance lines. The construction of model lines for long-distance operation can also be expected in the not-too-distant future. Interest has already been expressed from many areas throughout Japan, and there is widespread call for the construction of SCDV lines as today's new mode of transportation. Government studies are also making headway. In addition, the strong interest that is being voiced around the world is another indication of the expectations being placed in the SCDV as the next generation of transportation.

Although this new vehicle holds much promise, there are many areas which have yet to be developed. The development of materials can be expected to play a prominent role in furthering this development.

## REFERENCES

1) K.Oshima,Y.Kyotani,4th International Cryogenic Engineering Conf.1972
2) Y.Kyotani,ICEC5,1974
3) Y.Kyotani,CRYOGENICS 15,372,1975
4) T.Ohtsuka,Y.Kyotani,IEEE Transaction on Magnetics,vol.MAG-11,No.2,608,1975
5) T.Ohtsuka,Y.Kyotani,IEEE Transaction on Magnetics,vol.MAG-15,No.6,1416,1979
6) Y.Koyotani,International Symposium on Traffic and Transportation Technologies, 31,1979
7) T.Ohtsuka,Y.Kyotani,IAS Conf.Record,238,1980
8) Y.Kyotani,CONVERGENCE 80,1980
9) Y.Kyotani,RAIL INTERNATIONAL,156,1981
10) Y.Koytani,ICEC9,1982
11) H.Tanaka,Y.Kyotani,25th TRF,1983
12) T.Ohtsuka,Y.Kyotani,ICEC10,1984
13) Y.Kyotani,MT9,1985
14) Y.Kyotani,H.Tanaka,International Conf. on MAGLEV and Linear Drives,1986
15) M.Nagatomo,Y.Kyotani,IAF'86,1986
16) Y.Kyotani,TITANIUM for ENERGY and INDUSTRIAL APPLICATIONS

## Improvements to the Power Supply

The cycloconverter being planned as main power source equipment increases the power from 10 MVA to 16 MVA.

In order to conduct high speed running tests on the short test track (7 km), it is necessary to achieve greater acceleration and deceleration rates, so that these speeds require somewhat larger capacity than would be necessary on a commercial line.

Concurrently with the increased power, a new circulating current type system will be adopted. At the Miyazaki Test Center, current between 0 and 34 Hz has been supplied for test speeds between 0 and 500 km/h, but the conventional cycloconverter cannot convert the power up to one third of the input frequency. Therefore, the frequency has been raised to 120 Hz by a large sized motor generator (140 t), as it was not possible to use the 60 Hz current supplied directly from the electric power company.

The new circulating current type converter will have a large conversion frequency range, so it is possible to receive the power directly from the electric company and at the same time the output waveform has been somewhat improved (Fig.2).

To carry out the various tests, we need two three-phase cycloconverter sets (in total 6 units) for the complex feeding system, and two cycloconverter units have already been completed.

The coil for propulsion and guidance on the ground side itself, which is used to increase the voltage from 3000 V to 6000 V in high speed coupled operation, can be used essentially as is, so it will be used for the new tests after strengthening the insulated leads.

The changeover switch and transmission line need to be reinforced for high voltage and the length of one feeding section should be extended from 42 m to 58 m. After these changes, running tests for a two car train and a three car train will be carried out at 400 km/h and 350 km/h respectively.

## Production of a Prototype Vehicle

The superconducting magnets for MLU001 are arranged continuously along the vehicle in the longitudinal direction, but for commercial service we are designing a bogie type vehicle in which magnets are in the bogies and a smaller number of magnets are used.

The prototype vehicle will introduce recently developed results into various components, to check running performance and the total vehicle system. (Table 2, Fig.3)

The new vehicle will be designed to have 44 seats and the dimensions of the vehicle make it possible to carry 70 - 80 passengers in commercial service. The superconducting coil is a pregnant one made of niobium-titamium alloy intrinsically stabilized wire. Weight has been reduced by improving the copper ratio to 1, which is much smaller than the 2 of MLU001.

The superconducting magnet will have a persistent current switch and a power lead, which have been developed to realize high speed excitation and de-excitation. The on-board refrigerator, will be provided for each superconducting magnet as an individual refrigerating system. It has already been proved on the MLU001 vehicle that this system is better than a centralized refrigerating system.

For braking, in addition to a regenerating brake, a mechanical brake for emergency use will be installed on the vehicle.

The former ML500 vehicle employed a mechanical brake system that brakes by gripping the I-shaped steel plate installed on the guideway with brake shoes, but the new prototype vehicle will employ a sliding shoe type system to brake by frictional force directly on the guideway, and various basic tests have been carried out using a rotary type testing machine and the MLU001 vehicle.

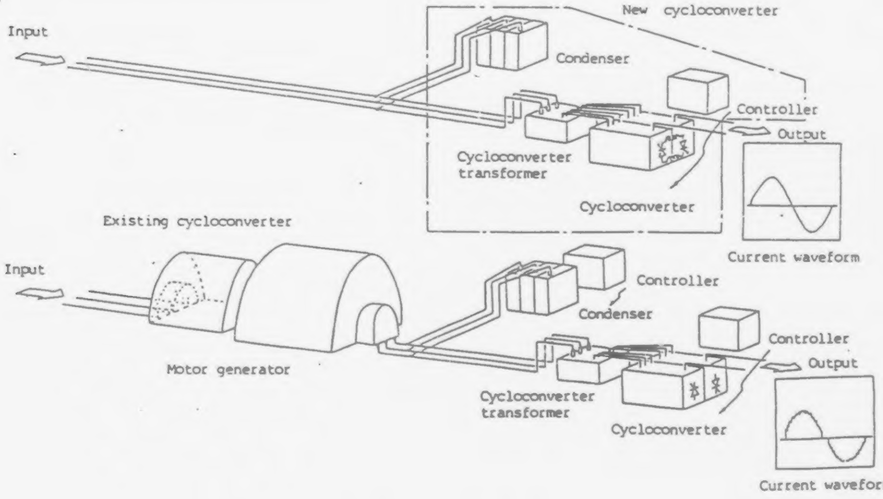


Fig. 2 Cycloconverter

Table 2 Main features of prototype vehicle

| | |
|---|---|
| Length x Width x Height | 22.0 m x 3.0 m x 3.6 m |
| Mass | 17 t |
| Maximum speed | 420 km/h |
| Levitation height (Effective gap) | 100 mm |
| Magnetomotive force of S.C.coil | 700 kA |
| Number of S.C.coils | 6 poles x 2 rows |

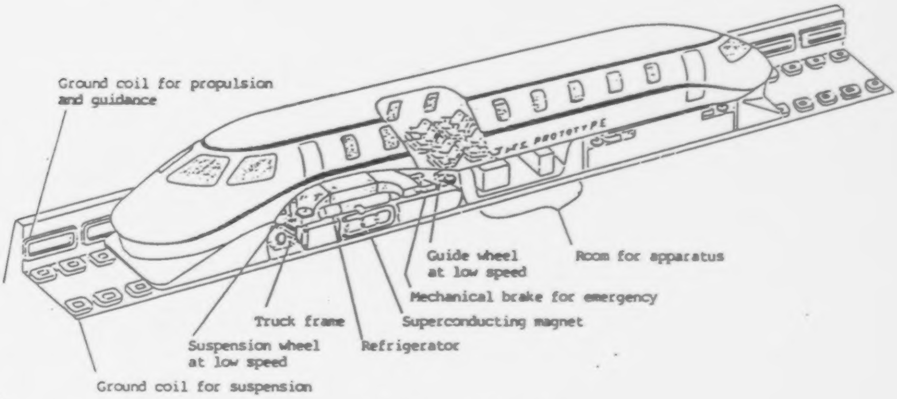

Ground coil for propulsion and guidance
Guide wheel at low speed
Room for apparatus
Mechanical brake for emergency
Truck frame
Superconducting magnet
Suspension wheel at low speed
Refrigerator
Ground coil for suspension

Fig. 3 Protype vehicle

## Burying of the Ground Coil

Strength and durability of the alminum ground coil, which was molded with SMC (sheet mold compound), have been studied sufficiently at the Miyazaki Test Center.

Many coils will be needed on the guideway, so we expect that the cost of the coils will be reduced. Though the ground coil was bolted to the surface of the guideway as shown in Fig. 4, the ground coil for commercial service will be buried in the concrete guideway, to simplify the structure and fastening for the coil.

For the levitation coil, we have been testing special concrete sections with the levitation coil buried in the slab for a long time, and for the propulsion and guidance coil we have developed special concrete sections with the coil in the same configuration (Fig. 5).

The propulsion and guidance coil shown in Fig.5 is the aluminum coil, molded with epoxy, for 20 kV use and it was designed to meet a long train.

At the Miyazaki Test Center, we have conducted running tests of Maglev vehicles for 8 years. There has been no damage to the ground coil because of noncontact operation, so we think that replacement of the ground coil is not often necessary.

Burying the coil in the concrete has an advantage for walking on the guideway, because the surface of the guideway is flat.

## Time for the Maglev System To Begin Commercial Service

Regular test running of the prototype vehicle will be conducted in fiscal 1987. This enables us to finally verify the maglev system.

At that stage, the following principles will be immediately used for commercial service at a maximum speed of about 400 to 480 km/h. In the active track linear motor system, one vehicle unit and one substation correspond to one another and one substation can cover a track about 50 km long. As the vehicles run with their wheels in contact with the turnout tracks only at stations where the vehicles should always stop, these turnouts can be simple, like ones for people-mover with rubber tires.

The ground coils as applied on the Miyazaki test track at present will be enough for a train unit with 5 or 6 vehicles.

In addition, for turnouts necessary for long distance operation of long trains, we are conducting partial trial production and tests of a traverser system; on the straight side, trains can pass levitating at maximum speed, and the turnout section, about 80 m long, is divided into 6 blocks.

For the case when the distance between stations is longer and a train runs through two substation sections, we are practicing simulation tests of substation control across the boundary between substations.

Also, we are developing a high-pressure-tight ground coil, illustrated in Fig. 5, which corresponds with a long train consist.

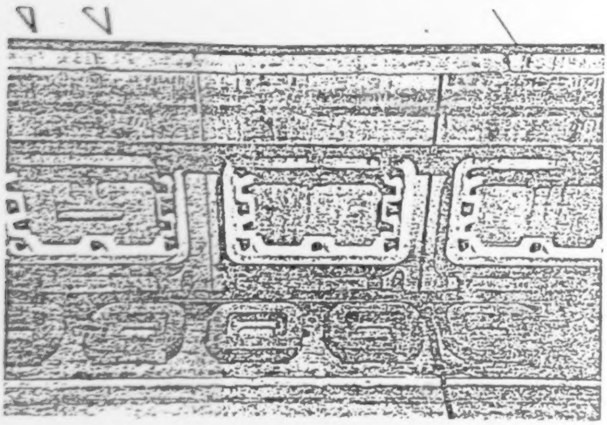


Fig. 4 Ground coils of Miyazaki test track

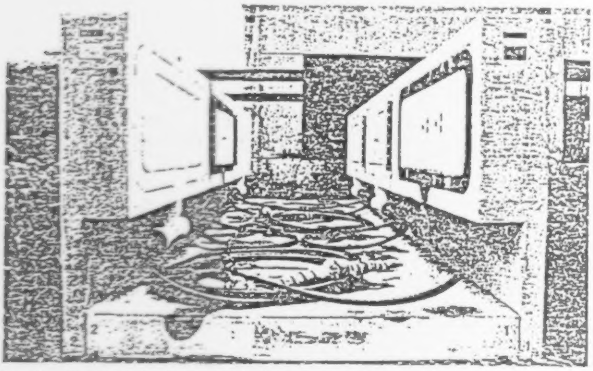


Fig. 5 Ground coil for propulsion and guidance burried in the concrete

Since, these do not pose any difficult problems, we will be able to put a long train in service over a long distance around 1990 and make the final test on a long distance test track, which will be constructed inadvance of its use in commercial service.

Safety of the Superconducting Magnet

The reason why JNR has been developing an electrodynamic system (EDS) which employs superconducting magnets is to make the effective levitation gap large enough by utilizing the strong magnetic force. However, a superconducting magnet for magnetic levitation is different from a magnet for a fusion reactor or a magnet for energy storage;

(1) Stored energy of the superconducting magnet is not very high. For example, stored energy of the MLU001 on the Miyazaki test track is 522 kJ/coil and that of the prototype vehicle, 540 kJ/coil. Even when the superconducting coil quenches and releases the stored energy for a moment, the temperature of the coil rises only to about 100 K without any damage to itself. At the same time, as the vaporized helium in the cryostat is released by the safety valve, there is not any danger such as explosion. Also, even if one coil quenches, the neighboring coils never quench even by magnetic coupling.

(2) The magnetic field is not so high. On the MLU001, the magnetic field of the coil section is 4.7 T at the Maximum and that on the surface of the magnet is 1 T at the maximum. As the magnetic field becomes smaller in inverse proportion to the square of distance, its intensity at a point 2 m to the side of vehicle becomes 0.005 T or below and does not have any influence on the surroundings. The floor of the passenger section, which is half of the MLU001 vehicle, is protected only by shielding steel plate of 2.3 mm in thickness; the magnetic field in the passenger

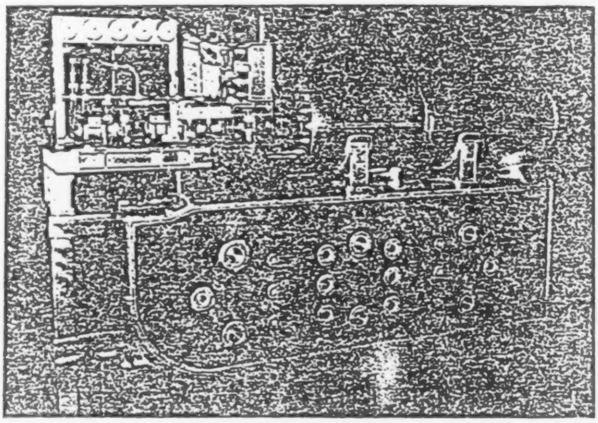


Fig. 6 Superconducting magnet

section, however, is within 0.02 T. On vehicles for commercial use, the magnetic field in the passenger section will be reduced further. If we try to achieve this only by employing shielding steel plate, the vehicle weight increases. So we are taking measures jointly to plan the coil arrangement and to maintain an isolation distance.

Thus, the superconducting magnet for the Maglev system is not strong enough to cause particular problems.

## Closing Remarks

The superconducting magnetically levitated transport system that JNR began to develop in 1970 is at last coming near to commercial use. Since the beginning of the development, we have aimed at establishing a simple system and could achieve this overall. In the future, we also intend to go on with development in the same way.

In Japan, at present, studies for Maglev system introduction have begun in Hokkaido, Saitama, Niigata, Yamanashi and elsewhere.

## References

[1] Y. Kyotani, "Magnetic Transport System Development in Japan", in *Proceedings 9th Magnet Technology Conference*, 1985.

[2] H. Tanaka, "Operational Experience of JNR's Maglev Test Train", in *Proceedings of the International Conference on Maglev Transport*, 1985, pp. 271-276.

# MAGNETIC TRANSPORT SYSTEM DEVELOPMENT IN JAPAN

Yoshihiro Kyotani

Japanese National Railways (JNR)
Marunouchi Chiyoda-ku Tokyo, JAPAN

Abstract - Research and development on two methods of magnetically levitated transport system have been under way in Japan. One of them is an attraction type of magnetically levitated linear induction motor propelled vehicle system. Japan Air Lines has undertaken research and development on this for commercial passenger service between Narita Airport and the center of Tokyo. The HSST-3, 13.8m in length and 16 tons in weight, has achieved levitated running with passengers on board on the grounds of TSUKUBA EXPO'85, which has been open since March 1985. The other method is a superconducting magnetically levitated linear synchronous motor propelled vehicle system, on which the Japanese National Railways has taken a leading part and has commenced research and development for its intercity passenger services. In December 1979, test vehicle ML500, 13.5m in length and 10 tons in weight, attained a speed of 517 km/h on the 7 km Miyazaki test track. In September 1982, test runs with men on-board were made with a new test vehicle, MLU001, 10m in length and 10 tons in weight, and in November of the same year, tests with a 3-vehicle coupled set were conducted. Tests results show that the test vehicles performed stable levitated running and the riding comfort was favorable. It is possible to make coupled vehicles levitate and run. The more the number of vehicles coupled increases, the more stable the riding comfort becomes. And even when artificial irregularities which would be impossible on conventional railway lines were introduced into the guideway, vehicles were stable. This is mainly because the repulsion type of magnetic levitation system was adopted and the interval between the guideway and vehicle could be kept greater than 10cm through the use of superconducting magnets.

## EARLIER DEVELOPMENT

In the early 1960s, the Japanese National Railways began to study the Linear Electric Motor as a propulsion system unaffected by friction between rails and wheels. In 1970, JNR suggested that an EDS (Electro-Dynamic System) was promising as an intercity passenger transportation system and started research and development.

On the other hand, an EMS (Electro-Magnetic System) was suggested for use as an urban transport system or an airport access system about 1972, and the research and development in this field was started.

### Electro-Magnetic System

The project which had been initiated as an urban transportation system was called "Development of a low pollution railway" and in 1975 an experimental vehicle EML-50 began test running. This vehicle combined an attraction-type magnetic levitation system in which support and guidance are separated and an on-board SLIM (single sided linear induction motor).

As a project for airport access, Japan Air Lines began research and development of an HSST (High Speed Surface Transport), and JAL started tests with the first test vehicle, HSST-01, in 1975 and the second, HSST-02, in 1977.

The HSST is a system which uses an attraction-type magnetic levitation system that combines suspension and guidance, along with an on-board primary SLIM system.

### Electro Dynamic System

JNR analyzed the requirements and the environmental problems for an intercity passenger transport system in 1968 through 1970, and from the results JNR reached the conclusion that EDS is promising for the future.

We then started with various laboratory tests. Next came a test program using a LSM (Linear Synchronous Motor), EDS test vehicle LSM 200 and a test vehicle ML 100 for LIM and EDS from 1972, leading to LSM and EDS test vehicle ML100A in 1975.

Through the success of these continuing experiments, we had to confirm the technical possibility of operation at 500 km/h under almost real conditions. Therefore, we built a facility for running tests, in Miyazaki, Kyushu, as shown Table 1.

The result was that a test vehicle ML500 recorded a maximum speed of 517 km/h in December 1979 and we did indeed confirm the possibility.

| | |
|---|---|
| Vehicle (ML500) | |
| Dimension: | |
| Length x Width x Height | 13.5m x 3.7m x 2.6m |
| Weight | 10 tons |
| Speed | 500 km/h |
| Levitation height | 250 mm |
| Supporting | Opposed-coil type |
| Guiding | Null-Flux type<br>(Used in combination LSM) |
| Propulsion | Linear Synchronous Motor |
| Brake | Regenerative brake<br>Rehostatic brake<br>Mechanical brake |
| Superconducting magnets | |
| Number of cryostats | 4 |
| Cryostat dimension: | |
| Length x Width x Height | 4.15m x 0.74m x 1.1m<br>L type |
| Number of coils | 4 in one cryostat |
| Coil pitch: Support | 2.1m |
| Guide | 2.1m |
| Coil dimension: | |
| Support: Length x Width | 1.65m x 0.3m |
| Guide : Length x Width | 1.65m x 0.5m |
| Ampere turns: Support | 250 kAT |
| Guide | 450 kAT |
| Persistent Switch | Thermal type |
| Track | |
| Total track length | 7 km |
| Coil pitch: Support | 0.7m |
| Guide | 1.4m |
| Coil dimension: | |
| Support: Length x Width | 0.45m x 0.33m |
| Guide : Length x Width | 1.1m x 0.7m |
| Power distribution | |
| Frequency changer: | |
| Motor | 60 Hz, 10 MW |
| Generator | 120 Hz |
| Cycro converter: Input | 120 Hz |
| Output | 0-33.1 Hz |
| Section length | 29.4m |

Table 1 Miyazaki test line facility

## PRESENT EMS DEVELOPMENT

At the International Exposition in Tsukuba, the 48-passenger HSST-03 is very popular among visitors and has been operated, carrying a lot of people, since March 1985. Table 2 shows the outline of the HSST-03 system and Fig. 1 shows its overall view.

This system has a gap sensor to maintain a 10 mm levitation air gap by controlling the current. It employs a combination system for suspension and guidance in this system are installed in positions shifted slightly from the center of the guide rail, and the guidance system controls the vehicle by generating lateral force through the current control to each magnet, keeping the total suspension force of the magnets at the same level. Table 3 shows the magnets and the magnetically excited devices.

The features of the SLIM of the HSST-03 are shown in Table 4. The reaction plate, which is laminated with two 5 mm thick aluminium plates, is installed on the iron rail for magnetic levitation, and a slip speed is used to lessen the effect by attractive force excited between the primary side and the secondary.

Current for propulsion is supplied to the primary side of SLIM by way of a current supply rail and a current collector through a VVVF (Variable voltage variable frequency) inverter located on the ground.

The body structure is semi-monocoque and made of aluminium alloy as its principal material.

In the HSST-03, a "module" of four magnets and one primary SLIM is attached to the body by an air spring, as shown in Fig. 2.

Three modules are installed in the longitudinal direction on each side under the body. By this placement design, smaller magnetic drag and higher stability of the module with respect to the rail are expected.

Brake systems in use are a reverse phase brake using SLIM, a mechanical brake that grips the rail with brake shoes and, for emergency use, a skid brake that slides along the rail.

| | |
|---|---|
| Magnet | |
| Length x Width x Height | 940mm x 220mm x 207mm |
| Current | 41.2 A |
| Nominal air gap | 11 mm |
| Magnet Power Supply | |
| Input voltage | 210 V |
| Chopping frequency | 2000 Hz |
| Continuous output current | 50 A |
| Maximum output current | 140 A |
| Weight | 16 kg |

Table 3 Particulars of the magnet and the magnet power supply

| | |
|---|---|
| Dimension: | |
| Length x Width x Height | 2831mm x 490mm x 70mm |
| Weight | 155 kg |
| Number of poles | 18 |
| Output | 15.5 kW |
| Maximum thrust | 1860 N |
| Maximum voltage (50Hz) | 104 V (Phase) |
| Maximum current | 190 A |
| Slip speed | 5.6 m/s |
| Reaction plate | 5 mm Al |
| Nominal air gap | 13 mm |

Table 4 Particulars of the LIM

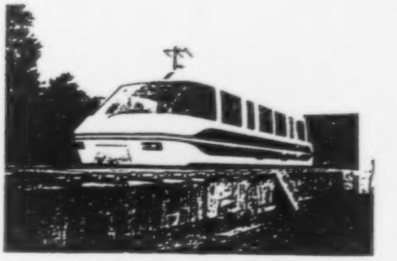


Fig. 1 - HSST 03

| | |
|---|---|
| Vehicle (HSST-03) | |
| Dimension: | |
| Length x Width x Height | 13.8 m x 2.95m x 3.00m |
| Weight: Net | 12 ton |
| Gross | 16 ton |
| Speed: Operating | 30 km/h |
| Maximum | 55 km/h |
| Levitation Air gap | 11 mm<br>Atractive type |
| Propulsion | Linear Induction Motor |
| Brake | Hydraulic brake<br>Electrical brake (LIM) |
| Number of modules | 6 |
| Number of seats | 48 (maximum) |
| Track | |
| Single lane, Double beam | |
| Length | 350 m |
| Maximum gradient | 0.3 % |
| Power supply (Propulsion) | 3-phase, VVVF |
| Maximum KVA | 380 KVA |
| Voltage | 40-550 V |
| Frequency | 5-100 Hz |

Table 2 HSST-03 System

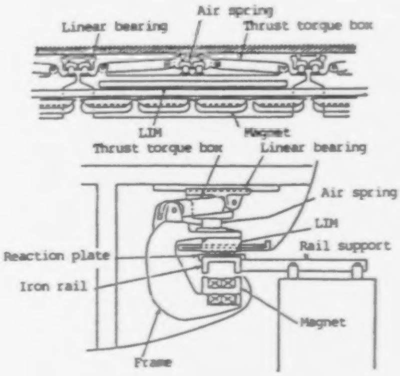


Fig. 2 - Scheme of module (HSST 03)

## PRESENT EDS DEVELOPMENT

### Miyazaki Test Track

After the ML500 tests, we decided, in order to carry out tests aiming at practical use, to conduct test runs using a box type test car with a small cross section and a low center of gravity.

The purpose of these tests is to operate a test car with men on it and to load a helium cooler on it, to get necessary data for making decisions about the cooling system to maintain the superconducting coils at low temperatures.

In addition, we are trying to confirm that cars can be coupled as a train, which is a feature of railways, and are operating three coupled cars to get necessary data for practical use. Because of limits on funds for research and development, we have decided to make effective use of the facilities at the Miyazaki Test Track, such as infrastructure, suspension coils, propulsion and guidance coils, power supply equipment and data transmitting devices that were used for ML500 tests.

Therefore, the standard length and weight of the test car was set at the same values, 10 m and 10 tons respectively. Accordingly, we have set the levitation speed at 180 km/h (ML500-120 km/h) and the maximum speeds for single car operation as 400 km/h, and for three coupled cars as 220 km/h (ML500-500 km/h).

Guideway. The configuration of the Miyazaki Test Track, where ML500 was operated, is shown in Fig. 3. This time we changed the shape of the cross section from inverted T-shape to a U-shape for test runs of the box-type cars, but the configuration of the test track was otherwise unchanged. Figure 4 shows the cross section of the guideway and a test car. In order to check the effect of the reinforcing steels in the guideway on the test car, we installed special sections, such as a section insulated from current flow between reinforcing steels and a section using low magnetic permeability steel, and also made it possible to measure steel current and magnetic fields around reinforcing steels as well as mechanical distortions and strains.

For prevention of overrunning by the test car, we installed aluminium plates for eddy current braking on both sides of the walls at the end of the running section. We also produced experimentally a guideway inspection car and a tractor when the shape of the cross section of the guideway was changed.

Power Supply Facility. As shown in Fig. 5, we have continued to employ the power supply facility used for running tests of the ML500. However, taking the running tests of the 3-car train into consideration, we altered the section length of the propulsive and guided coil group which supplies propulsive electric power, from 29.4 m to 42 m. Also, for ML500 we needed an average acceleration and deceleration of 12 km/h/sec to achieve more than 500 km/h on a test track with a length of 7 km, and for that reason we needed just to control electric power of high levels. With MLU001, we have been able to control electric power at low levels to conduct running tests with men on-board.

Along with these the running tests, research and development of the power supply facility have continued and the results have been proved on the test track. At present, construction work on a circulating current type 16 MVA cycloconverter is now moving forward at a new substation for the Miyazaki Test Track and then it will be possible to conduct running tests at higher speed.

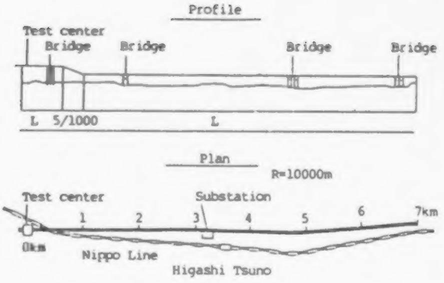


Fig. 3 - Outline of Miyazaki test track

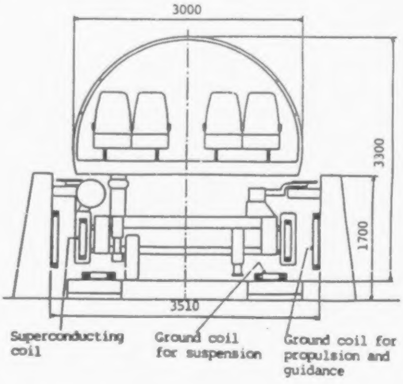
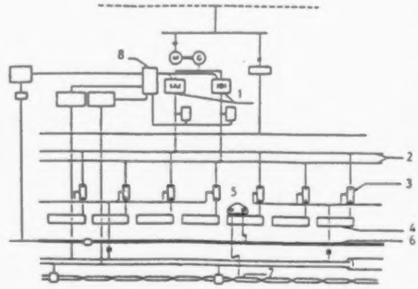

3000
3300
1700
3510
Superconducting coil
Ground coil for suspension
Ground coil for propulsion and guidance

Fig. 4 - Cross section of U-shaped guideway and vehicle (MLU 001)



1: Cycloconverter 2: Feeder 3: Changeover switch
4: Coil for propulsion and guidance 5: Vehicle
6: Leakage coaxial cable
7: Inductive wire with transposition
8: Total control board for power distribution

Fig. 5 - Outline of the LSM control and power supply system

## MLU001

Vehicle. We call the test vehicle with box-type cross section MLU001, ML represents Magnetic Levitation and U indicates that the U-shaped guideway is used for the vehicle running tests. The three vehicles, are numbered in consecutive order MLU001-1, MLU001-2 and MLU001-3. Main features of MLU001 are shown in Table 5 and the outline of coupled -1, -2, and -3 test vehicles in Fig. 6. The structure of the test vehicle is designed with the car body installed on the bogie frame equipped with superconducting magnets, and shock absorbers such as air springs and oil dampers are installed between the car body and the bogie frame. For tests when the front vehicle runs independently or when only the front and middle vehicles run coupled, and also for tests of the shape of the vehicle's head, we attach a removable structure on the end of the car body.

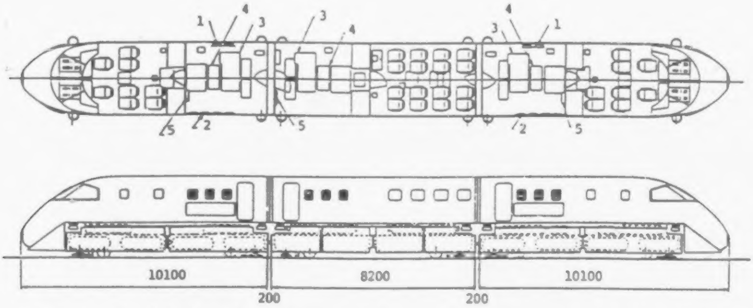
On MLU001, one superconducting coil fulfils its function to suspend, guide and propel vehicles and four of these coils are installed on each side of the lower part of the car body, being put in line on the bogie frame. Since the inductive repulsion type magnetic levitation system does not levitate at a low speed, this test vehicle has four supporting wheels and four guiding wheels under the bogie frame for lower speed running, and when the running speed of the vehicles reaches a specified speed, those wheels are retracted into the body or extended out from it. In case the wheels do not work properly, emergency landing shoes can be used.

The car body has a semi-monocoque structure, and is built mainly of aluminum alloy. The inside of the car is divided into two compartments, so as to be convenient for tests; one is designed for measurement, control, and for specialists concerned to be on board and carry out various kinds of tests and to check the riding comfort, and the other is equipped with power supply facilities such as batteries and inverters and information transmission facilities. An optical fibers information transmission system is used for information transmission between the coupled vehicles.

In MLU001, batteries are used for the on-board power supply, and while the test vehicles are stopping at the starting point, the batteries are charged from facilities on the ground through charging rails and electric power collecting shoes. However, as inductive and non-contact electric power collection is considered desirable for practical use, it is possible to conduct such tests to meet practical needs.

| | |
|---|---|
| Vehicle dimension: | |
| Length x Width x Height | 10.1m x 3.3m x 3.0m<br>(End Vehicle)<br>8.2m x 3.3m x 3.0m<br>(Mid. Vehicle) |
| Weight | 10 ton |
| Electrodynamic suspension | |
| Levitation force | 98 kN |
| Levitation height | 240 mm (between coils) |
| Effective gap | 100 mm |
| Null flux guidance | |
| Guidance force | 49 kN at 50 mm shift |
| Distance between coils | 355 mm |
| Effective gap | more than 150 mm |
| LSM propulsion | |
| Propulsion force | 51 kN |
| Phase | 3 |
| Frequency | 0-27 Hz |
| Voltage | 3,000 V |
| Current | 1,100 A |
| Brake force | |
| Regenerative | 51 kN |
| Generative | 25 kN |
| Mechanical | 8 kN |
| Maximum speed | |
| 3 vehicle train | 220 km/h |
| Single vehicle | 400 km/h |

Table 5 Main features of MLU 001



1: Antenna for inductive wire with transposition
2: Antenna for leakage coaxial cable
3: Battery
4: Inverter
5: Switchboard

Fig. 6 - Outline of the connected MLU 001-1, 2 and 3 test vehicles

**Superconducting Magnet and Refrigerator.** The reason why the weight of MLU001 could be kept to 10 tons, the same as that of ML500, even though MLU001 carries a helium refrigerator and has testing equipment and men on-board, is that the number of superconducting coils could be reduced by using them jointly for the three functions of suspension, guidance and propulsion, and also that a thoroughly researched and highly developed superconducting magnet, cooling devices and helium refrigerator could be used.

Each vehicle employs superconducting coils as shown in Table 6 and a light, compact and more heat-resistant superconducting magnet was produced with improvement of each element of the power lead, thermal persistent current switch, and load suspension device. Weight and heat invasion per unit of stored energy of the superconducting coils are one tenth of those of the magnet used in the initial stage of the development.

To continue research and development of the arrangement of the superconducting magnets and the combination of the superconducting magnet and helium refrigerator, we produced two types of cryostats as shown in Fig. 7. The upper figure shows that two superconducting coils are kept in one cryostat (2coils/cryo), and the lower figure shows one superconducting coil in one cryostat (1 coil/cryo). The 2 coils/cryo method is used on the first and third vehicles and the 1 coil/cryo method on the second vehicle.

Figure 8 shows the cross section of the 2 coils/cryo type superconducting magnet equipped with helium refrigerator and this syste is cooled indirectly by a re-condensed heat exchanger. Figure 9 shows a schematic diagram of the on-board refrigerator systems for the MLU001.

The features of the superconducting magnet with helium refrigerator for the third vehicle are as shown in Figure 10. The long, narrow cylinder on the upper part is the helium tank and the short cylinder is the Claude cycle refrigerator; these two cylinders are connected with low-temperature pipes. As four magnets with refrigerators and one helium compressor like the one in this figure are installed on the third vehicle, the total amount of heat invasion into the lower temperature pipes in the complete vehicle is very small. Compared with the cryostat holding two or more superconducting coils, the 1 coil/cryo method is unfavorable from the viewpoint of weight as well as heat invasion, but since its structure is simple, improvement of its reliability can be expected. Also, by promoting standardization of the superconducting magnet and refrigerator system in one unit, this will aid minimization of manufacturing costs and improvement of efficiency of vehicles installation. So we have developed the cryostat for the 1 coil/cryo method and the small sized helium refrigerator; manufactured the superconducting magnet with helium refrigerator system, including helium compressor, for trial and tested them; and further employed the 1 coil/cryo type superconducting magnet put in one body with a helium refrigerator on MLU001-2.

The refrigeration cycle used for the MLU001 helium refrigerators is mainly the Claude cycle, but for the second vehicle the hybrid stirling-JT (joule Thomson) cycle is also used. This JT cycle is pre-cooled by the Stirling refrigerator. Samples of specifications for the Claude refrigerator and hybrid Stirling-JT refrigerator are shown in Table 7 and 8.

| | |
|---|---|
| Dimension of racetrack coil | 1.7m x 0.5m |
| Magnetomotive force | 700 kAT |
| Dimension of coil winding | 49mm x 78mm |
| Operating current | 700 A |
| Inductance | 2.13 H |
| Maximum magnetic field | 4.7 T |
| Stored energy | 522 kJ |
| Weight of conductor | 100 kg |
| Type of winding | solenoid type and impregnated |
| Superconducting wire | Nb-Ti |
| Copper ratio | 2 |
| Dimension | 1.2mm x 2.6mm |

Table 6 Superconducting coil parameters

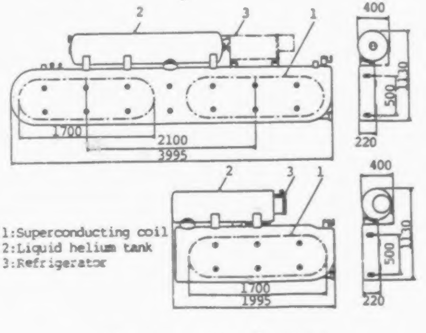


Fig. 7 - Section of cryostat

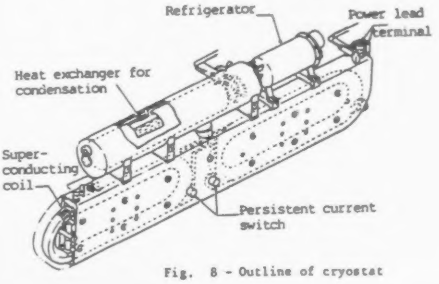


Fig. 8 - Outline of cryostat

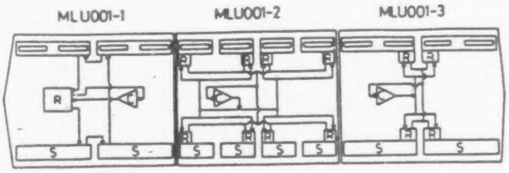


Fig. 9 - Schematic diagram of the on-board refrigerator systems for the MLU 001

S:S.C.Magnet, C:Compressor, R:Refrigerator

| | |
|---|---|
| Refrigeration capacity | 5 W at 4.4 K |
| Cycle | Claude |
| Inlet pressure | 16 atm |
| Flow rate | 30 $Nm^3/h$ |
| Dimension: | |
| Diameter x Length | 300mm x 800mm |
| Weight | 40 kg |

Table 7 Specifications of 5W Claude refrigerator

## Running Tests

Table 9 shows the procedures used in the running tests on the Miyazaki test track. Data for tests started with ML500 in July 1977 to running tests started with MLU001-1 in November 1980 are limited to bare essentials in this table. At present, MLU001-1 has run approximately 30,000 km in 6,500 running tests.

In November 1980, running tests were started using 4.1 km of the U-shaped test track and the front vehicle equipped with a structure for reverse running, and in November 1981 running tests were started with the front and rear vehicles coupled. Consequently, we could confirm that running with two vehicles coupled was stable. As the reconstruction of the whole 7 km test track into U-shape was completed in May 1982, we increased the speed of running tests with two vehicles coupled, and the speed attained was 305 km/h in July 1982, the limit speed with the present capacity of electric power supply. Meanwhile, the reconstruction of the LSM power supply equipment, the study of vehicle movements and the verification of performance of emergency equipment have been carried out and it became necessary to have tests of running comfort with riders and various kinds of tests with on-board equipment. Two-vehicle (MLU001-1 and MLU001-3) running tests were made for the first time with riders in September 1982. The riders reported good running comfort and got useful data as expected. The middle vehicle, MLU001-2 of the three-vehicle test train, was constructed in November 1982 and then ran on the Maglev test track. The three-vehicle train's running was better and safer than that of the two-vehicle train and the electric power supply capacity served well for a maximum speed of 222 km/h of the three-vehicle train.

From February 1983, to get necessary data on guideway design, construction and maintenance, a variety of irregularities were temporarily added to the guideway, as shown in Fig. 11. Two-vehicle, travelling at 300 km/h, was able to pass over even a series of 30 mm high and 61.6 m long humps with a gap of 60 mm. The speed was nearly the resonance speed; however the damping of vibration was satisfactory. Other running tests were made after setting irregularities to the ground coils as shown in Fig.12, and setting a low rigidity beam. JNR confirmed that guideway conditions were adequate and safe for Maglev running. The tests of no-contact current collection by a single vehicle and two-vehicle set confirmed that practical use was possible. The distribution of magnetic field in the vehicle was checked and 200 gauss was indicated at floor level. This is equivalent to a no-hazard condition because 200 gauss is treated as the design standard as the design for test vehicles, but the JNR plan for commercial vehicles must be less than present levels.

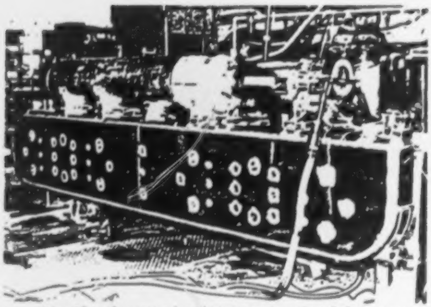


Fig.10 - Superconducting magnet and refrigerator (MLU 001-3)

| | |
|---|---|
| Refrigeration capacity | 5 W at 4.4 K |
| Cycle | JT-Stirling hybrid |
| Joule Thomson loop | |
| Flow rate | 0.854 g/s |
| Inlet pressure | 18.9 $kg/cm^2G$ |
| Weight | 13.5 kg |
| Stirling refrigerator | |
| Sealed-in pressure | 16 $kg/cm^2G$ |
| Frequency | 4.9 Hz |
| Phase angle | -90° |
| Piston stroke | |
| Compression | 58.6 mm |
| Expansion | 25.0 mm |
| Weight | 19.2 kg |
| Total weight | 33.4 kg |
| Dimension: | |
| Diameter x Length | 292mm x 796mm |

Table 8 Specification of 5 W JT-Stirling refrigerator

| | |
|---|---|
| 1977 July | Running tests started with ML-500. |
| 1978 Nov. | 347 km/h achieved on 4.7 km - section. |
| 1979 Jan. | Simulated tunnel running tests started under MOT sponsorship. |
| May | Running tests began with ML-500R. (Helium refrigerator on-board) |
| Dec. | 517 km/h achieved on 7 km - section with ML-500. |
| 1980 Nov. | Running tests started using U-shaped guideway and MLU 001-1. |
| 1981 Apr. | 251 km/h achieved on 4 km - section. |
| Nov. | Running tests started with two vehicles coupled. (MLU 001-1 and 3) |
| 1982 July | 305 km/h achieved on 7 km - section. (MLU 001-1 and 3) |
| Sept. | Running tests started with man on-board. (MLU 001-1 and 3) |
| Nov. | Running tests started with three vehicles coupled. (MLU 001-1, 2 and 3) |
| 1983 Feb. | 222 km/h achieved. (MLU 001-1, 2 and 3)<br>Running tests started by setting irregularities on the guideway. |
| July | 400 km/h achieved. (MLU 001-1) |
| 1984 Feb. | Running tests started by setting irregularities in the fixing of the ground coil. |
| Mar. | Running tests started using a section with low stiffness beam. |
| Mar. | Running tests started with a two-vehicle consist plus rear body. |
| 1985 Feb. | Running tests started by setting irregularities in the fixing of the ground coil. |

Table 9 MAGLEV development on the Miyazaki test track

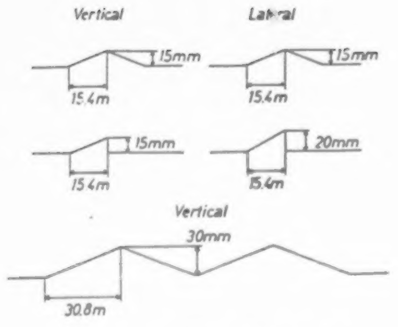

Vertical
Lateral
15mm
15mm
15.4m
15.4m
15mm
20mm
15.4m
15.4m
Vertical
30mm
30.8m

Fig. 11 - Guideway irregularity test

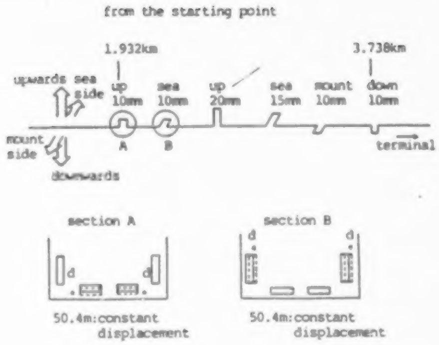

from the starting point
1.932km
3.738km
upwards sea side
up 10mm
sea 10mm
up 20mm
sea 15mm
mount 10mm
down 10mm
mount side
downwards
A
B
terminal
section A
section B
d
d
d
d
50.4m:constant displacement
50.4m:constant displacement

Fig. 12 - Ground coil irregularity test

Helium Refrigerator

The Ministry Transportation has been subsidizing the Maglev transportation costs, but the JNR is also entrusted with research for the Science and Technology Agency on small size, high efficiency Helium Refrigerators as a development and study project on basic technology. The target of this study is to have a Helium Refrigerator system which can be used down to 4°K by the Stirling Cycle, called the samll size and high efficiency Helium Refrigerator. In 1982, the target of the study could be reached from the 10-15°K level by the Stirling Refrigerator to the 4°K level, and this was to test the cooling system in the very low temperature range. In 1983, a 3.74°K minimum temperature was reached by the Stirling Cycle. As the result, the study and test of this part was continued and data obtained for cooling from liquid nitrogen temperature (about 78°K) level to the 4°K level which could be done by the Stirling Refrigerator, as shown in Fig. 13. This showed that a cooling capacity of 2 watts or greater worked well. From this time on, JNR has a plan to develop this refrigerator by producing the coolness from the ordinary temperature. So that it can produce the necessary low temperature starting from ordinary temperatures.

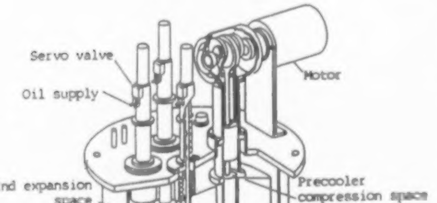

Servo valve
Oil supply
Motor
2nd expansion space
1st expansion space
4-5K cooling
Regenerator
Precooler
compression space
expansion space
Heat exchanger
Vacuum vessel

Fig. 13 - Scheme of Stirling refrigerator

CONCLUSION

Magnetic transport system development has been eagerly pursued in Japan. HSST-03, an electromagnetically levitated (EMS) linear induction motor propelled vehicle system by Japan Air Lines, is very popular with visitors to Tsukuba EXPO'85. MLU001 of the Japanese National Railways in Miyazaki is attracting much attention with its high speed and style, and it is a superconducting magnetically levitated (EDS) linear synchronous motor propelled vehicle system. Most visitors to the Miyazaki Maglev Test Center asked these questions: the time of development completion plans in the future, economic evaluation, the limit of the maximum high speed and influence of magnetic force.

The time of development completion, by some difinitions and what we have already said, seems to have come to the goal because the present Maglev system is a practical system. This system, however, has one of the best roles: to provide better transportation to the public. We think that JNR will be able to have adequate, satisfactory confirmation to meet the people's need for reliability and conservativeness. As the plan for the future, we should show here the following; to continue the present tests and to progress toward the completion of superconducting magnet development now under way, the on-board cooling system and other systems. We would also like to finish by having a new type power supply system which can show the better speed of MLU001 vehicles. If we can get enough money for study and development within 3 years, we may have better prototype vehicles and a turnout system for the Maglev running tests.

In the economic evaluation in 1981, they calculated and showed the construction cost of this Maglev system to the public as 20 percent higher than that of a Shinkansen system. But from our recent trial calculation, the cost is shown as the same as the Shinkansen or less. When the construction of a Maglev system of less than 50 km is going on, these Maglev system merits will be reconsidered and the cost will be less than Shinkansen construction. The technology of superconducting magnets, low temperature equipment, power electronics system, optical information system and other systems and the development of materials brought these better results. Especially, this Maglev system showed more than 10 cm levitation running and in future 500 km/h running will be conducted and introduced to the public. This Maglev system railway will open a new and hopeful line for the magnetic industry.

## REFERENCES

(1) K. Oshima, Y. Kyotani - "The Japanese magnetically suspended train project" - in Proc. 4th International Cryogenic Engineering Conf., Eindhoven May 1972

(2) Y. Kyotani - "Development of superconducting levitation trains in Japan" - in Proc. ICEC 5, Kyoto, May 1974, CRYOGENICS 15, 372, July 1975

(3) T. Ohtsuka, Y. Kyotani - IEEE Transaction on Magnetics, vol. MAG-11, No.2, 608, 1975

(4) T. Ohtsuka, Y. Kyotani - IEEE Transaction on Magnetics, vol. MAG-15, No.6, 1416, 1979

(5) Y. Kyotani - "Development of electrodynamically suspended transport system in Japan" - In Proc. International Symposium on Traffic and Transportation Technologies, 31, Hamburg June 1979

(6) T. Ohtsuka, Y. Kyotani - "Recent progress in superconducting magnetic levitation tests in Japan" - IAS Conf. Record, 238, September 1980

(7) Y. Kyotani - "Running tests on superconducting magnetic levitation system" - in CONVERGENCE 80, Dearborn September 1980

(8) Y. Kyotani - "Present status of research and development of superconducting magnetic levitation railway - Research on linear motor magnetic levitated system in the Japanese National Railways" - RAIL INTERNATIONAL, 156, April 1981

(9) Y. Kyotani - Proc. ICEC 9, 1, Kobe 1982

(10) T. Ohtsuka, Y. Kyotani - "Recent progress on superconducting magnetic levitation in Japan" - Proc. ICEC 10, 1984

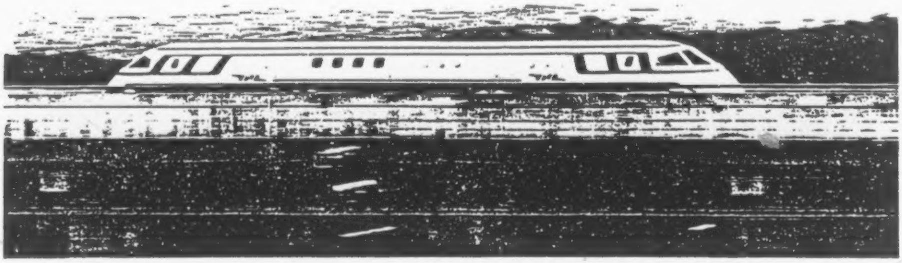


Fig. 14 - Connected MLU 001-1,2 and 3

# MLU002 PROTOTYPE MAGLEV AND FUTURE PLAN

Yoshihiro Kyotani*
Hisashi Tanaka**

## Introduction

Since April 1987, the Railway Technical Research Institute (Foundation) has succeeded to the maglev development conducted by Japanese National Railways in former days.

## Test results of MLU001 vehicles

After the completion of the improvments to the power supply system for the Miyazaki test track, high speed running tests with use of MLU-001 vehicles were carried out to the maximum speed shown below.

| | |
|---|---|
| Dec.,1986 | 352 km/h by 3-car train |
| Jan.,1987 | 405 km/h by 2-car set |
| Feb.,1987 | 400.8 km/h by 2-car set, manned operation |

The total running distance of MLU001-1 car exceeded 40,000 km, and the running test with MLU001 vehicles was over for the time being.

## MLU002 prototype maglev

A prototype maglev, MLU002, was completed in March 1987 (see Table 1, Fig. 1, Fig. 4). In EDS system, superconducting coils having opposite polarity are arranged alternately in the longitudinal direction (see Fig. 2), and in MLU001, they are arranged continuously under the car body. On the contrary, in MLU002, superconducting coils are arranged intermittently in such manner as NSN--SNS, and concentrated on the bogies. The reduction in the number of superconducting coils is effective for the weight reduction , cost saving, and so on.

The superconducting magnet has three coils,made from niobium and titanium alloy as before, but the copper ratio was reduced from 2 on MLU001 to 1 on MLU002. The outer vessel is separated into three pieces, while the liquid helium tank is one piece. The superconducting magnet on one bogie has a Claude cycle refrigerator, while the magnet on the other bogie has a reversed Stirling cycle one (see Fig. 3).

## Proposed commertial vehicle

For the commertial train, it is planned to introduce an articulated structure. The floor is lowered between bogies to reduce the vehicle height. Under this design, the air resistance of the train and the magnetic flux density in the cabin could be reduced to a large extent (Table 2, Fig. 5).

* Technova Inc. 13th Fl. Fukoku Seimei Bldg., 2-2 , Uchisaiwai-cho 2-chome, Chiyoda-ku, Tokyo 100, Japan
** Railway Technical Research Institute, 2-8-38, Hikari-cho, Kokubunji-shi, Tokyo 185, Japan

Table 1 Main parameters of MLU002

| | | |
|---|---|---|
| Vehicle dimensions | Length x Width x Height | 22.0 m x 3.0 m x 3.7 m |
| | Mass | 17 t |
| | Seating capacity | 44 |
| Superconducting coil | Number of coils | 6 poles x 2 rows |
| | Magnetomotive force | 700 kA |
| | Pole pitch | 2.1 m |
| Suspension | Lift | 196 kN |
| | Effective gap | 110 mm |
| Guidance | Guidance force | 83.3 kN at 50 mm shift |
| | Effective gap | more than 150 mm |
| Propulsion | Thrust | 0-79.4 kN |
| | Phase | 3 |
| | Frequency | 0-28 Hz |
| | Voltage | 5800 V |
| | Current | 900 A |
| Maximum speed | | 420 km/h |

Table 2 Design specifications of commercial system

| | | |
|---|---|---|
| Maximum speed | | 500 km/h |
| Vehicle dimensions | Length x Width x Height | 28.0 m x 2.8 m x 2.65 m (E)<br>21.6 m x 2.8 m x 2.65 m (M) |
| | Mass | 27 t (E)<br>18 t (M) |
| | Seating capacity | 67 (E)<br>68 (M) |
| Train | Number of vehicles | 14 |
| | Length | 315 m |
| | Mass | 270 t |
| | Seating capacity | 950 |
| Superconducting coil | Length x Width | 2.2 m x 0.5 m |
| | Pole pitch | 2.7 m |
| | Magnetomotive force | 700 kA |
| | Number of coils | 4 (2 poles x 2 rows) |
| Ground coil for s* | Length x Width | 0.6 m x 0.3 m |
| | Pitch | 0.9 m |
| Ground coil for p*&g* | Length x Width | 1.5 m x 0.6 m |
| | Pitch | 1.8 m |
| | Voltage | A.C. 19 kV |
| Levitation height | | 100 mm |
| Midway between tracks | | 5.4 m |
| Curve radius | | over 6000 m at 500 km/h |
| Maximum gradient | | 10 % |
| Continuous gradient | | 6 % |

(E):End car, (M):Middle car
s*:suspension, p*&g*:propulsion and guidance

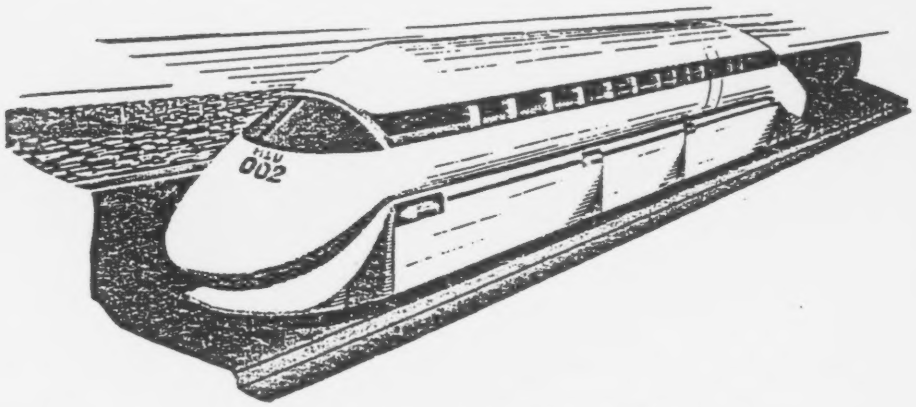


Fig. 1 MLU002 prototype maglev

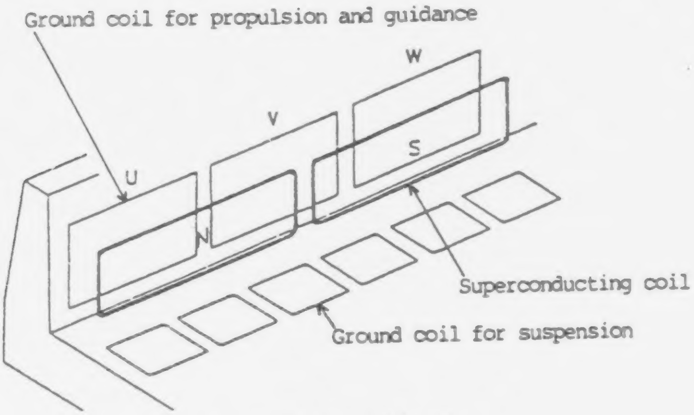

Ground coil for propulsion and guidance
W
V
S
U
N
Superconducting coil
Ground coil for suspension

Fig. 2 Coil combination

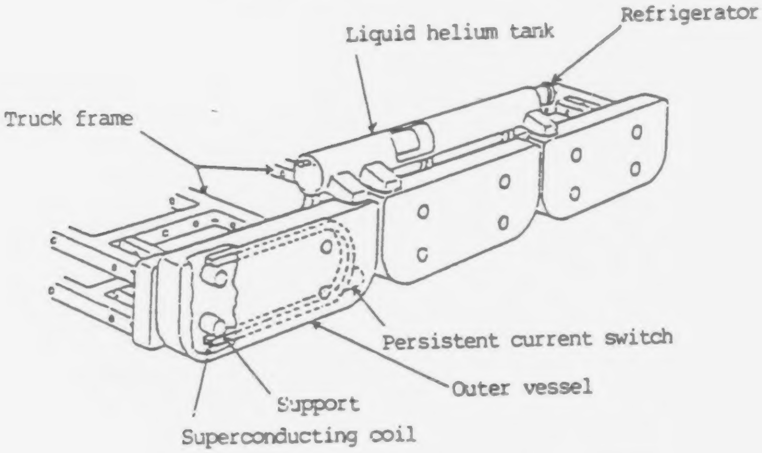

Refrigerator
Liquid helium tank
Truck frame
Persistent current switch
Outer vessel
Support
Superconducting coil

Fig. 3 Superconducting magnet for MLU002

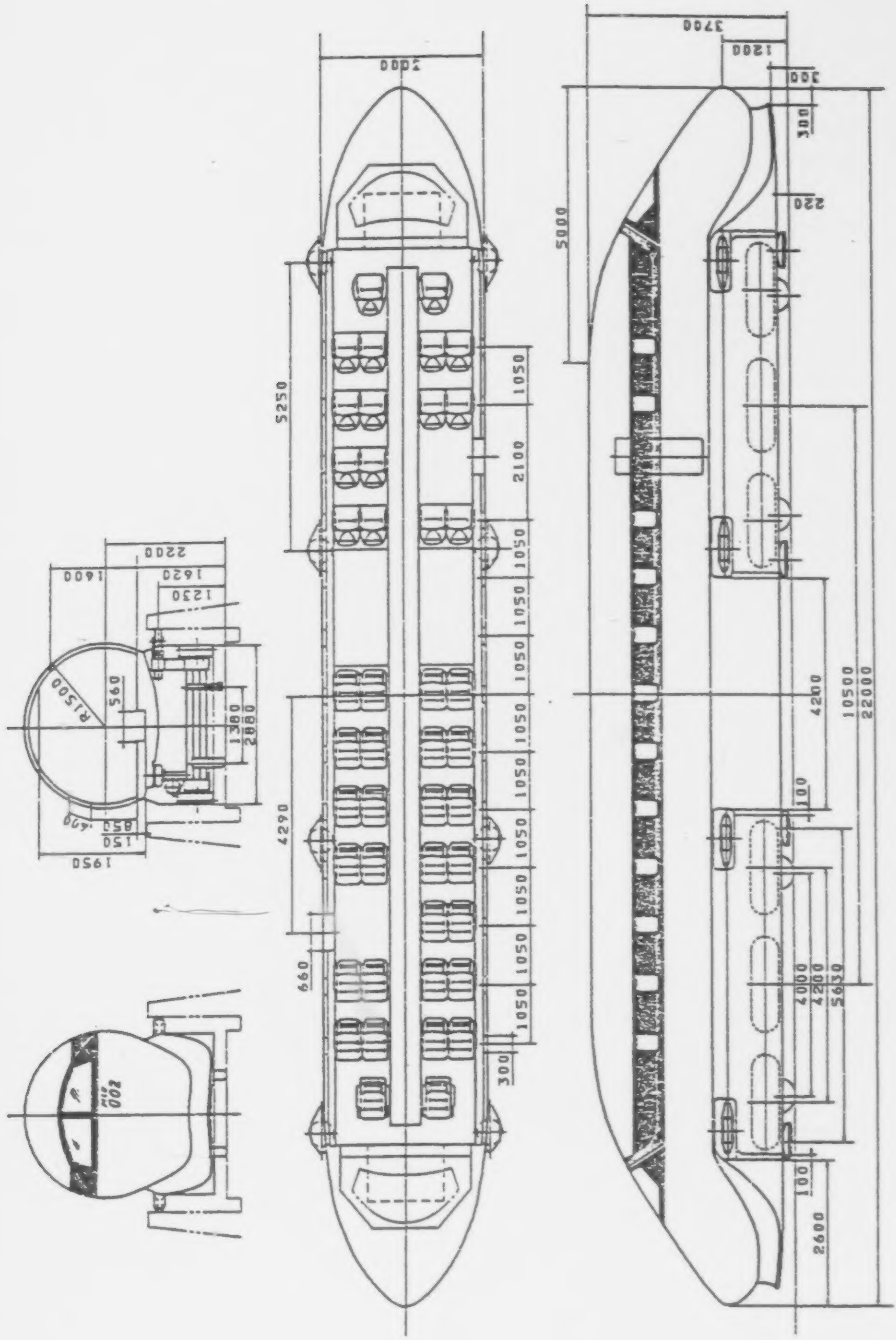

2000
3700
1200
300
300
220
5000
5250
1050
2100
1050
1050
1050
1050
1050
1050
1050
1050
1050
4290
660
300
1950
150
850
1600
2200
1620
1230
R1500
560
1380
2080
MLU 002
4200
10500
22000
100
4000
4200
5630
100
2600

Fig. 4 Plan of MLU002 prototype maglev

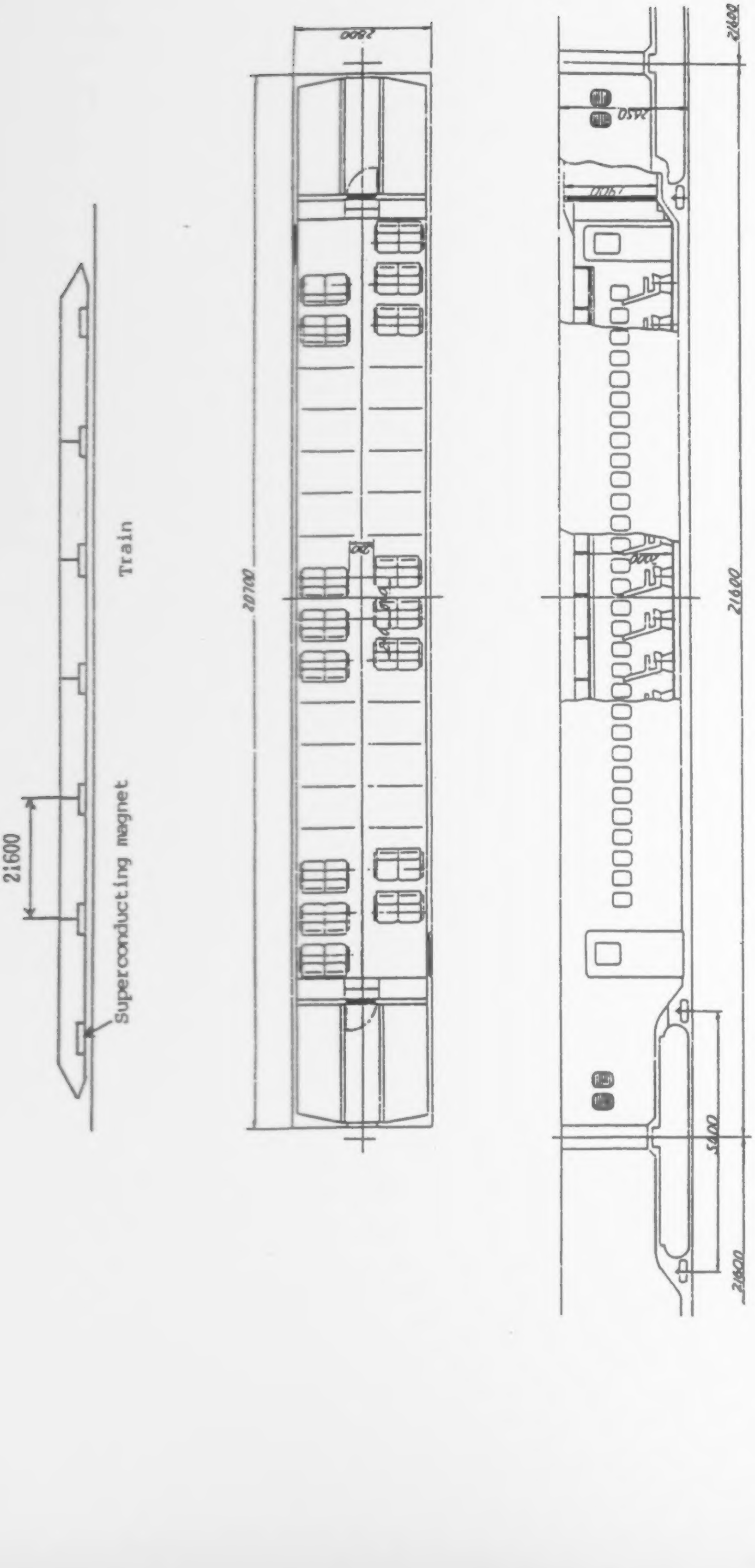

21600
Superconducting magnet
Train
2800
20700
21600
2450
5400
21600

Fig. 5 Proposed commercial vehicle

Senator MOYNIHAN. We are going to begin with Doctors Powell and Danby, who have an announcement of a committee which we are forming to prepare a report for the President, to be submitted in February. And, Dr. Powell, why don't you proceed.

## STATEMENT OF JAMES R. POWELL, BROOKHAVEN NATIONAL LABORATORY

Mr. POWELL. Good morning, Senator Moynihan and members of the committee. I welcome the opportunity to appear again to discuss the importance of Maglev to the United States.

This morning I would like to review the potential payoffs from Maglev and what is needed to make it happen. I would also like to describe the formation of an ad hoc study group to assess the role of Maglev in the United States. This group, formed at the request of Senator Moynihan, will study how Maglev can be implemented using the present rights-of-way along the U.S. interstate.

My colleague, Dr. Danby, will review the present status of Maglev technology and discuss some advances that appear possible.

Five requirements have to be met before Maglev can be implemented. We have to have a practical technology; available rights of way; acceptable economics; financing sources; and an effective government policy.

To a significant extent, these requirements depend on each other. For example, some Maglev approaches might be technically practical, but too expensive for widespread use.

Dr. Danby will discuss this interdependence. With some technology development, we believe that the twin goals of practical technology and acceptable economics can both be achieved.

The availability of rights-of-way along interstate highways is vital to the widespread application of Maglev. Not only do new rights-of-way cost a lot, but they often arouse a great deal of opposition. And I will return to the issues of financing and government policy in a minute.

But first, let me review the potential importance of Maglev to the United States. It can help to: preserve mobility, reduce pollution and environmental damage, cut oil imports, reduce transportation costs, and provide new manufacturing opportunities.

As an example, we have been considering the application of Maglev to our home region, Long Island. Approximately 90,000 people each day commute on the Long Island Expressway, which is also called the world's longest parking lot, with at least as many on the other main roads. Another 60,000 people per day commute on the Long Island Railroad.

Assuming that a Maglev system running along the center of Long Island could carry 150,000 passengers per day for an average round trip distance of 100 miles, we can estimate the corresponding benefits.

Commuting on Long Island is almost a second job. Many people spend several hours a day on the road. With a conservative savings of two hours per day, approximately 100 million person hours of time would be saved each year—a tremendous social and economic benefit.

Typically, Long Island commuters obey the Pauli exclusion principle. They drive singly, and avoid car pooling, which increases traffic and pollution. The above Maglev system would save approximately 8 million barrels of oil a year. This is equivalent to the oil needed for the generation of 600 megawatts of electricity—almost as much as the Shoreham nuclear plant.

Burning this amount of gasoline produces approximately 50,000 tons a year of air pollutants—sulfur dioxide, nitric oxides, hydrocarbons, and ozone. As you drive in Long Island, along the highways, you can often see extensive local tree damage alongside the highways. The leaves have turned brown, well before their normal time.

Burning this gasoline also adds 2 cubic kilometers per year of pure carbon dioxide to the atmosphere, a significant contribution to the greenhouse effect, which has aroused such concern.

Senator REID. Mr. Chairman, are we still talking only about the——

Mr. POWELL. Long Island.

Finally, many of the people using the Maglev system would be part of a family with more than one automobile. The reduction in wear and tear on autos, plus the opportunity to reduce the number of cars in the family, would save hundreds of millions of dollars per year in this region.

This is a small example of the benefits of the benefits that Maglev could provide. Long Island, that is, the counties of Nassau and Suffolk, comprise about one percent of the U.S. population. Further, in this example, the assumed ridership for the Maglev system is only about 8 percent of the Long Island population.

If Maglev were to be applied on a nationwide basis, it is easy to see that the total benefits would be hundreds of times greater than those sketched out for the Long Island application.

Other regions of the U.S. can allow practical Maglev systems. In many areas, such systems will be easier and lower in cost than for Long Island. Long Island is relatively built-up. There's not as much right-of-way. It still is practical to build Maglev there, but if you go to the Interstates in other parts of the country, it will be a much easier job.

Although Maglev appears to be a promising new mode of transport for the United States, more detailed studies and assessments are needed, including examination of what kinds of funding sources and strategies would be desirable. Options involving partnerships between public and private sectors appear particularly interesting and attractive.

At the request of Senator Moynihan, a Maglev assessment group has been formed. The group will review the status of Maglev technology, what improvements can be expected, and how it can be used in the United States.

The study will focus on the feasibility of using the right-of-way along Interstate Highways for Maglev routes. Technology advancements that can reduce cost and enhance implementation will be investigated. The study will also assess potential environmental and economic benefits, explore financing options, and examine the U.S. industrial capability for Maglev.

The study will address the following main issues:

Is Maglev important to the United States?

Is present Maglev technology practical, and can it be improved?

Can it be used along Interstate Highway rights-of-way?

Are the projected economics favorable?

How can systems be financed?

And is a U.S. Maglev program desirable?

The members of the assessment group have extensive experience with Maglev technologies and applications, and come from a variety of industrial, academic and geographic backgrounds. The members are all participating on a voluntary nonfunded basis.

Dr. Danby and I have offered to act as coordinators to collect and organize the contributions of the study group members. The Grumman Corporation has offered to help prepare the final report, which will be delivered to Senator Moynihan in early February 1989.

I would like to read into the record the names and backgrounds of the study group members, and to express my grateful appreciation for their willingness to undertake such a difficult but vital job.

The group members include, besides ourselves, Mr. Anthony Bright, from Mechanical Technology Incorporated organization in Albany, New York; Dr. Howard Coffey, one of the original workers in Maglev, who is now working for Argonne National Laboratory; Professor Harry Fair, from the Center for Electromechanics, at the University of Texas, a former senior executive at DARPA; Dr. Richard Gibbs, who is chief of the Automotive Emissions Lab in the New York State Department of Environmental Conservation; Dr. Richard Gran, who is the Director of Advanced Projects for Grumman; Dr. Larry Johnson, who is the Director for Center for Transportation Research at Argonne National Laboratory; Dr. Henry Kolm, who is Chairman of EML Research in Massachusetts, who is one of the original pioneers in this field; along with him, his coworker, Professor Richard Thornton, from MIT; Mr. Fred Robertson from McLellan and Robertson in New Orleans, who has been doing extensive work in looking at Maglev in the Southern States; Dr. Carl Rosner, who is President of Intermagnetics General, a leading company manufacturing superconductors and associated technologies in New York; and Dr. Robert Salter, Chief Executive Officer of Xerad, who has been for a number of years looking at very high speed magnetic levitation systems for cross-country applications.

We anticipate that other members of the group will be added, again with the idea of keeping it broad-based and covering all the technology aspects of Maglev.

If the study concludes that Maglev should be developed and implemented in the United States, it is our hope that the effort will be only a first step towards a U.S. program.

It is my personal view that for the United States to catch up with, and to ultimately advance beyond the present Maglev systems, it will be necessary for the government to play a major role. Besides helping to fund R&D, it will have to formulate policies that minimize obstacles and delays in Maglev development and application.

In conclusion, I wish to thank the committee for the opportunity to testify on this promising and very important technology.

Senator **Moynihan**. Dr. Powell, those are extraordinary numbers. Two cubic kilometers of $CO_2$ from the Long Island Expressway alone. I have a list here of the study participants, and it doesn't include Dr. Kolm's associate, Gorton, did you say?

Mr. **Powell**. Thornton, yes.

Senator **Moynihan**. Oh, it is. It's two pages.

Mr. **Powell**. Listed alphabetically, right.

Senator **Moynihan**. We'll discuss later the arrangement. It's very generous of Grumman, but we have to see that you do have the resources you need for this. You've done your work, obviously. It's mostly just to get the other talk, but we will surely arrange that, and I will take it on myself to see that it is done.

Mr. **Powell**. Thank you.

Senator **Moynihan**. Let's go right on then. Dr. Danby.

## STATEMENT OF GORDON DANBY, BROOKHAVEN NATIONAL LABORATORY

Mr. **Danby**. Good morning, Senator Moynihan and Senator Reid.

In February, we outlined how Maglev works, and this morning I'm going to review briefly some questions relating to its application.

Now, what is the present status of Maglev technology? Apart from various study efforts over the years, there are two serious ongoing efforts.

The Japanese National Railway, pursuing concepts invented by Jim Powell and me, have developed demonstration vehicles and test track systems that show that very high speed Maglev transport is practical. After years of testing, including demonstration passenger carrying vehicles, they are ready to build and presumably export these high speed, large clearance magnetically levitated and propelled superconducting train systems.

Meanwhile, using a different very small clearance magnet approach, the German Transrapid system has also undergone very extensive development and is ready for implementation and presumably for export.

Now, some have suggested, why don't we just buy these foreign systems?

There are several good reasons why we should not accept this passive role.

The existing Maglev systems are first embodiments; in the future these will appear as dated and quaint as early automobiles or airplanes.

We and others already have ideas for more advanced concepts to efficiently move passengers plus goods. No doubt additional breakthroughs will follow as major deployment of Maglev occurs.

We should not be parochial. Let the Japanese and Germans and other start-up efforts compete for first applications here. However, we are not behind in developing the mature relevant systems needed for future widespread use in the U.S.A. This assumes, of course, we decide we care enough and put in the necessary effort in the near future.

All have benefited from the foreign pioneering. We do not have to establish that Maglev works and that it can be safe and reliable for very high speed transport applications.

If a public-private sector combination effort can be launched, U.S. industry is up to the task of rapidly going forward. The necessary superconducting and refrigerating technologies exist in U.S. industry. Indeed, much of this technology was developed here first, as in the case with the pioneering Maglev ideas.

Finally, we are still the leaders in aerospace technology. Maglev can properly be viewed as closer to aerospace than to heavy wheeled train technology. Very low cost, light weight, low drag vehicle and guideway systems seem essential for large scale application in the U.S. The industrial skills exist here to leap-frog the earlier efforts.

Desirable features of a widespread Maglev system applied to the U.S.A. is my next topic.

This is a very large and diverse country. Energy efficient, very fast transport is relevant not only to densely populated corridors, as Jim described, but ultimately to interconnecting cities which are widely separated by regions of low population.

The use of the interstate highway network for Maglev is an excellent idea. Much of the system is very straight and contains adequate space for both the existing highways and for vehicle guideways, suitably isolated for mutual safety. If I can ad lib, it really is. For the last 6 months I've been observing those systems, and they are eminently suited in the vast majority of cases.

This interstate approach overcomes the greatest cost and availability impediment, obtaining guideway real estate.

The existing foreign vehicle and passenger tracks seem unduly expensive and are not necessarily sufficiently flexible to be compatible with economically sharing interstate rights-of-way.

Assuming interstate land is free, the guideway is the major remaining cost factor. A low cost guideway to provide both the levitation and the linear synchronous drive motor, becomes very attractive.

Compared to Japan and Europe, the U.S. is large and has comparatively low population density. We can benefit more from cost-effective large scale mobility.

Much of the U.S. is flat, lending itself especially to low cost systems. This is particularly important during the earlier phase of implementation, before widespread public use has been demonstrated.

In fact, if I may ad lib again, recently having driven to Rochester, and having seen, Senator, your excellent article reviewing the history of New York State and the evolution westward of the country via the Hudson and Mohawk and Erie Canal, the area, when you get a little north of New York, to Albany, to Buffalo, is, as other parts of the country, areas where it's obvious this could be done, extremely cheaply, to get the whole thing rolling in a hurry. In fact, one of my high energy colleagues, my chairman, said to tell you to throw in Boston as well, and then get started across the country. But that's not ours to decide.

But those are the kind of places, probably, to start, from a purely economic point of view siting issues are beyond our comprehension and capacity to influence in any way.

Transportation historically is fundamental to land use and industrial development—the ultimate core industry. It can directly produce transportation-related domestic employment on a very wide scale, and can produce large export business, such as our aircraft companies enjoy.

The indirect benefits of widespread Maglev will be even greater. New areas and resources would be efficiently interconnected, impacting on land use and raising living standards. This is based on its speed and low energy costs which result in a greatly increased mobility.

Finally, such a new major application of superconductivity would lead to other high tech spin-off industries, no doubt, occurring here rather than happening abroad.

Now, there are some critical questions for Maglev.

Is it safe?

The Japanese National Railroad has a long history of experiments which demonstrate stable 300-mile-per-hour levitation and propulsion, producing a very smooth ride. Levitation, propulsion, acceleration, and braking all employ theoretically very simple inherently stable systems. Tracks have been displaced by several inches with no ill effects. Demonstration passenger vehicles have been used, although the test track is short.

It is also possible to enhance the fail-safe features of the superconducting magnets beyond the design the JNR used in their excellently performing demonstration.

Maglev is simpler than aircraft and will be better controlled than private autos are. It should be intrinsically safer than either of these.

The major safety question is keeping large foreign objects out of its way. (By which I mean cars, refrigerators, not Japanese or Germans.) If placed at grade, or above grade on columns, the necessary isolation is essential. For interstate highway applications, earthworks will be required to protect support columns from trucks which accidentally leave the roadway. Otherwise cut and fill tunnel installation can be used.

Now, what about superconductors?

We are all aware of the recent potentially very important progress on high temperature superconductors. If applicable in the future to Maglev, these could have some very attractive features.

These improvements are, however, incremental. It is not necessary to have advanced superconductors to build Maglev. The existing magnets are relatively simple compared to many other superconducting magnets in use. The magnets and refrigerators are a modest part of the cost and weight of the Japanese vehicles, which in turn are a very small cost compared to right-of-way development and guideway costs.

It is noted that roughly 1,000 large, ultra precise, superconducting magnets produced by industry are employed successfully today in MRI medical scanners, which I happen to be personally involved with, and I have a long history in superconducting magnets. So the magnets required for Maglev are not something that will happen tomorrow, they're here now. There is nothing wrong with conventional superconductors. They are quite satisfactory. New breakthroughs can only improve the situation.

Finally, can Maglev succeed in the U.S.A.?

Maglev will not replace the car or truck, or, indeed, the airplane. It can, however, complement them and greatly enhance the total transport system.

The great flexibility and freedom of individual activity permitted by the car and truck is unique. In the U.S.A. they largely ran the railroads out of business. Will the same fate await Maglev?

A critical difference is that the speed of the car and truck equal that of the train. When the necessary road system was in place, it also became cheaper to use the "free" road, dooming large scale general use for railroad trains. Railways provided less mobility at greater cost.

The situation is entirely different with Maglev. The Maglev system is much faster and more energy efficient, providing potential for mobility much greater than previously known. Note that mobility is dominated by travel time and by cost, which is fundamentally energy. Long trips in short times can become routine.

Another factor today is that the car, truck, highway system is choking on its own success, and often is deteriorating.

In conclusion, the Maglev system will be mutually supportive with the existing transportation systems. Widespread Maglev use of piggy-back freight modules and of car ferries can even be anticipated.

Thank you very much for the opportunity to speak to you today.

Senator **MOYNIHAN**. Thank you, Doctors. That was very encouraging testimony. I hear two things, one is that the German and Japanese have moved ahead where we have not. But what they have done was to establish from the Powell-Danby theses that it obviously will work, it will fly. But the one that flies is not going to be the one that will be flown. They've established that it's workable now to move to the models that you actually would produce is Stage 3, and we can enter Stage 3 with the benefit of a billion dollars worth of Japanese experimental work. I think that's an assuring thought.

Second is that the interstate system rights-of-way are there and are usable and are essential. I hear that very powerfully.

I've got to ask Dr. Powell, what is the Pauli exclusion principle?

Mr. **POWELL**. Two objects can't occupy the same space at the same time, or two particles can't occupy the same space at the same time.

All right, sir. We are now going to hear from David Rush, and I know that his Senator and friend, Senator Graham, would like to introduce him.

I wonder if you would do that, sir.

## OPENING STATEMENT OF HON. BOB GRAHAM, U.S. SENATOR FROM THE STATE OF FLORIDA

Senator **GRAHAM**. Thank you, Mr. Chairman. I would like to ask consent to submit an opening statement which, in part, discusses the destination that all that transportation that left New York wanted to get to in Florida.

Senator **MOYNIHAN**. Without objection.

[Senator Graham's statement follows:]

## Opening Statement of Hon. Bob Graham, U.S. Senator From the State of Florida

Mr. Chairman, I want to express my appreciation for the ability to participate in these hearings on magnetic levitation technology and it's application to mass transportation.

I also want to take this opportunity to applaud Senator Moynihan and his foresight and determination in bringing this issue to the Congress. Our chairman is not bringing a plan of the future before us today—the future is now for mag lev trains and their development.

In the nineteenth century, trains opened up Florida for development. In the twentieth century, the interstate highway system and jet airplanes have made Florida accessible to millions, and it is the high speed rail which will keep Florida moving into the next century.

Florida is facing an unprecedented demand on its transportation system. In 1987, the population of Florida was 11 million. By the year 2000, it will be over 15 million. In 1987 we had in excess of 35 million tourists visit our State and the estimate is that by the year 2000 almost 60 million tourists will come to Florida. In 1986, on our seven major highway corridors, we had an average of 700,000 daily trips; by the year 2000 those same corridors will be expected to carry 1.4 million daily trips.

In many respects we are continuing a dependence on technolocial developments of almost a centruy ago and on investments made largely in the previous decade and earlier. In the State of Florida, for example, it is estimated that in order to meet projected traffic demands, 44 lanes will have to be added between Miami and West Palm Beach by the end of the next decade. More highways are not the answer.

The question now facing us is not will we develop high speed rail systems, but when we will begin? How far behind the world will we allow ourselves to fall before we move into the future? I am proud to say that in Florida, much thought and planning has gone into meeting future needs and Florida is poised to take that next giant step. Many States are right behind us and I hope that this comimttee will send a signal that this country is prepared to meet head-on the challenges of the future.

I am anxious to hear from our distinguished witnesses and excited to hear about the feasibility of using our Federal rights of way to aid in development of mag lev trains.

Thank you.

**Senator Graham.** I also appreciate your holding this series of hearings on this important subject, and particularly focus today on how we can provide the necessary corridors to make this a feasible undertaking.

A gentleman who has had substantial experience and given deep thought to these questions is the new Chairman of the Florida High Speed Rail Commission. David Rush has served our State in many capacities. He is also chairman of the Governor's High Technology and Industry Council. He is the chief executive officer of two high tech firms in our State, ACR Electronics and Aptek Microsystems. He has been a civic leader in many areas of education, of economic development, of the application of high technology to the solution of current problems.

I am very pleased that our State has a citizen of his quality and that he can share his experience with this committee.

**Senator Moynihan.** Thank you.

We welcome you, Mr. Rush.

## STATEMENT OF DAVID H. RUSH, MEMBER, FLORIDA HIGH SPEED RAIL TRANSPORTATION COMMISSION, AND CHAIRMAN, FLORIDA HIGH TECHNOLOGY AND INDUSTRY COUNCIL, ACCOMPANIED BY TIM LYNCH, ASSISTANT DIRECTOR, FLORIDA HIGH SPEED RAIL TRANSPORTATION COMMISSION, AND KAREN ANTHONY, ENVIRONMENTAL SPECIALIST

Mr. RUSH. Thank you, Senator Graham, for that wonderful introduction.

Mr. Chairman, Senator Reid. I appreciate the opportunity to report on our State's efforts already under way to bring magnetically levitated train travel to Florida.

With your permission, I would like to introduce two of my colleagues that are with me today. Dr. Tim Lynch is Assistant Director of Florida High Speed Rail for Economic and Environment. And Ms. Karen Anthony is Environmental Specialist assigned to the High Speed Rail by the Florida Department of Environmental Regulation.

Senator MOYNIHAN. Dr. Lynch and Ms. Hanson were introduced earlier. We welcome you to this hearing room.

Mr. RUSH. And they are here to help me field any questions, since they are experts in economics and environment.

My remarks, very briefly, are submitted in a much more detailed written report.

Senator MOYNIHAN. We will place it in the record.

Mr. RUSH. Thank you. In Florida, we're accustomed to thinking in terms of large scale high tech developments. We are home of NASA's Kennedy Space Center and Disney's EPCOT. Our legislature readily appropriates money to compete for such futuristic endeavors as Spaceport Florida and the Super Collidor/Super Conductor projects.

In the transportation field, Florida is the acknowledged national leader in planning for high speed train systems. Both the Federal Railroad Administration and the International High Speed Rail Association attest to that.

Florida realized the need for high tech transportation alternatives over 10 years ago when it began studying the feasibility of high speed rail including Maglev, and thanks to then Governor Graham.

The 1984 High Speed Rail Act set the stage for privatization of new transportation systems that would benefit the State economically, environmentally, and in the focusing and management of our tremendous growth. We add over 300,000 new residents a year, who put a huge strain on all of our infrastructure, particularly our transportation facilities.

The program would also benefit the private sector by providing economic incentives such as property development benefits, the possibility of tax exempt bonds, and perhaps most important for today's testimony, the availability of transportation right-of-way for the corridors. As we have developed our plans over the past 3 years, the commission has studied, visited and traveled on most of the high speed rail and Maglev systems throughout the world. Representatives of industry and governments in Japan, Europe, and the United States have offered serious proposals for both Maglev and high speed rail systems for Florida.

Our commission is now reviewing two private sector applications to build a 300-mile high speed rail system, 90 percent of which uses existing and, in many cases, publicly owned transportation right-of-way. Although no Maglev technologies were proposed for the 300-mile system, we are surging forward with a new high tech transportation project, a Maglev train project that could catapult our transportation capabilities into the 21st Century.

Due to the interest and encouragement of the Commission, and certain representatives of Maglev technologies, the State Legislature, the past year, enacted the Florida Maglev Demonstration Project Act. The act authorizes the commission to select a plan for a commercial operating Maglev line for construction in Florida. This act requires us to select the Maglev plan by next June; and, therefore, Japanese and German systems are the most likely proposals. I might add that they have teamed up, and I will put this into the record. I won't read it. But it says, "Rivals Team Up on High Speed Rail. Japanese Would Use German Trains."

Senator MOYNIHAN. That will be placed in the record.

[The article referred to follows:]

[From the Orlando Sentinel, September 16, 1988]

## RIVALS TEAM UP ON HIGH-SPEED RAIL

### JAPANESE WOULD USE GERMAN TRAIN

Mag-Lev of Florida, a Japanese company seeking permission to run a high-speed train between Walt Disney World and Orlando International Airport, has teamed up with a rival West German company that might have one of the advanced trains available in just over a year.

The partnership was made necessary because the Japanese government has been skittish about exporting its super-conductivity technology that propels the train. Superconductivity allows high amounts of electricity to travel without resistance. The German company, Transrapid International, doesn't use superconductors to magnetically levitate the train, but it is considered about five years ahead of the Japanese in testing.

Mag-Lev will rely on the Germans to provide the train, which resembles a monorail but can hit speeds of up to 300 mph. In turn, Transrapid can take advantage of the homework the Japanese company has done in preparing an Orlando route and getting financing.

The German-Japanese partnership was announced almost indirectly at a Thursday meeting of the Florida High Speed Rail Transportation Commission, which next year will grant a license to one company to build what is considered a "demonstration" project.

The merger shows how committed Mag-Lev is to getting the job, said Orange County Commissioner Linda Chapin.

"It really advances it one step into the realm of reality," she said. "I'm beginning to think these people are really serious."

At the rail meeting, Sam Tabuchi, president of Mag-Lev's land acquisition company, introduced a covey of associates who are working on the project. Among those introduced was William Dickart, a consultant to Transrapid. Only when the rail commission's members asked about the implication of Dickart's association did Tabuchi acknowledge the German involvement.

Mag-Lev had been the only company interested in the project until last spring when HSST of Las Vegas, Nev.—another Japanese company—said it also was interested. Both companies have said they will build the train at no expense to taxpayers.

Although HSST's trains are slower and less advanced—they use earlier technology licensed by Transrapid—they have offered to run not only between the airport and Disney but to connect the route with downtown Orlando as well.

That offer seemed to make HSST more attractive to several local politicans and planners.

Although he was surprised by news of the partnership, Dave Grovdahl, transportation planner for the East Central Florida Regional Planning Council, still had reservations.

"Besides serving Disney and the airport at 300 mph, what can you do for making the system available for local use as well?" he asked.

Commissioner Vera Carter had similar thoughts. "I really think that for any company to get exclusive rights for a rail system that cannot at least have a tie-in for some expansion is not a good idea," he said. "And I'm hoping that the high-speed rail commission would not allow that."

But Tabuchi and his colleagues seemed to think that adding the German technology widens the gap between Mag-Lev and HSST. The German government has spent nearly $1 billion in helping Transrapid develop the technology; the $800 million Disney-airport project is being financed by a Japanese bank that is the world's largest.

An HSST representative, however, said he didn't think the addition of the German company gave an edge to Mag-Lev. Romy Mowbray said he thought it unfair that the state was only allowing one demonstration project when several sites in South Florida would qualify.

Thursday's meeting focused chiefy on the rules under which the rail commission would operate. Although Mag-Lev obejcted, the commission avoided a rule that could have severely reduced the amount of information on the contract that would be public.

Mag-Lev had wanted to keep a wide range of topics confidential, including ridership surveys. But the commission agreed to limit the confidentiality to technical matters that are considered trade secrets.

It will be next spring before the rivals have to submit their applications and a $500,000 application fee. HSST sounded a little less certain Thursday that it would do so, saying only that it's "possible" it will apply.

If Mag-Lev wins the contract, it may have the train shutting silently between the airport and Disney within three years, according to Robert Cox, the company's attorney. That would mean Orlando would beat several German sites in showing off the new technology.

"We're hoping to be the first," Cox said.

Mr. RUSH. They're ganging up on us.

However, we also want to improve and advance Mag-Lev technology for use and application elsewhere in Florida and the United States. We will encourage and foster continued research and development of this new form of transportation technology as part of our Florida program.

We are not fantasizing about the future or spending these countless hours on a Buck Rogers project. The Florida High Speed Rail Transportation Commission has been in this business too long to be swayed or seduced by something that isn't feasible.

Maglev is feasible and more importantly, Maglev will bring benefits and opportunties. The commission will soon be seeking applications from private sector interests to finance, build and operate a Maglev project. It would demonstrate the feasibility of Maglev in a revenue setting and provide a Florida show case for Maglev technology.

It is a step along the way to our transportation future.

Maglev systems would, one, introduce another high industry to Florida; two, further privatization efforts with a transportation system that pays its own way and doesn't go on the taxpayers' dole; three, provide a transportation alternative to the critical transportation and infrastructure needs; and four, help relieve the strain on our highway and airport systems.

The Maglev systems themselves are: fast because it rides on a frictionless cushion of air; good for the environment because, as we just heard, because it needs a minimal amount of land, unlike roads; air and noise pollution minimizers; visually pleasing and quiet.

Not only does it have all these advantages, it can integrate into and therefore enhance the overall transportation network.

There is an important choice to be made: multiple lanes of new highway and the accompanying burdens on the environment and quality of life, or the use of that valuable right-of-way to encourage 21st century advances in transportation technology and environmental responsibility.

To us, it's an easy choice. This committee has proposed those solutions.

And, Senator, as an aside, I would like to thank you and Senator Graham and Senator Chiles for the work that you have done in the technical corrections amendment of the tax bill regarding the high speed rail amendment to get tax relief under it.

Senator MOYNIHAN. Tax exempt bonds. Yes, sir. And I think that should be very clear that it was Senator Graham who came to us on the Finance Committee and asked that that be done, and we are increasingly in the habit of doing things that he suggests be done, because they are so decisively put.

I think that's extraordinary testimony.

Mr. RUSH. We want to be the first. We think we will.

Senator MOYNIHAN. Well, Nevada and California are close on your heels. But there are two places where this is happening in this country, neither of which is New York, I take notice, where we began the transportation systems, many of them. But that is the rule of life.

Now, let's see. We have two remaining witnesses. I think, Mr. Parsons, you are historically associated with the beginnings of governmental research. Why don't you go next and then we'll hear from Dr. Choate.

Mr. PARSONS. Yes, sir.

## STATEMENT OF ROBERT E. PARSONS, SPECIALIST AND MANAGER, PROGRAM FOR ADVANCED TECHNOLOGY, INSTITUTE OF TRANSPORTATION STUDIES, UNIVERSITY OF CALIFORNIA, BERKELEY

Mr. PARSONS. Mr. Chairman, Senators Reid and Graham, with your permission, I would like to insert my prepared statement in the record and summarize it with a 5-minute version.

Senator MOYNIHAN. Without objection.

Mr. PARSONS. Your bills address very important issues that have bothered me during most of my career at DOT. Congratulations for your wisdom and courage to give new innovative transportation systems at least a chance of being considered as partial solution of the country's pollution, traffic congestion, energy, and safety problems.

As this committee knows, advanced ground transportation has not been given an even playing field when it comes to government support. Should a magnetic levitated Maglev vehicle, a high speed rail vehicle, or any other advanced ground system be economically and sociably acceptable, there is nowhere to go for Federal assistance as there is for a highway expansion or a new airport. Your bill, S. 2072, addresses this issue, at least for Maglev systems. My main suggestion is to have it broadened in scope to include other advanced ground guided systems.

I also agree with the underlying thrust of your other bill, SB 1794. America has lost her transportation technology leadership.

What you have so eloquently highlighted as the Maglev situation represents "just the tip of the iceberg" of lost opportunities in transportation during the last decade or so.

Other countries support transportation R&D that is high risk and long range, and foreign industries cooperate and perform the near term R&D. However, in our country in the U.S. transportation scene, there is no Federal long range R&D anymore. DOT tends to work on very, very short range issues. That's the reason I left that agency after 16 years in the senior executive service, because I could no longer support the policy that the United States would have a second rate ground transportation system. That policy has continued, and today we are in deep trouble in all ground transportation.

Today European auto makers and their governments plan to spend $700 million in research in the next seven years on the Prometheus program alone, to research cars and roads of the future, and Japan is installing an Advanced Mobile Traffic Information and Communication System (AMTIC) in Tokyo that will provide drivers with route information, traffic congestion predictions, travel aid information such as parking availability, hospital locations, and so forth, and is also investigating the next high tech industry, one pertaining to an Intelligent Vehicle/Highway system. Experts say this latter industry will dwarf the current P.C. market in terms of computer content. It's also going to impact our infrastructure in this country.

Currently, I am Director of the Program on Advanced Technology for the Highway, PATH, which is a bold California Department of Transportation initiative to address urban highway congestion, safety, pollution, and energy use, particularly in the larger California cities. Specifically, PATH is investigating unique noncontact electrified road propulsion systems for use on the most congested sections of our freeways. We also plan to demonstrate the value of on- board navigation devices on cars that permit two-way communication with freeway electronic control centers to provide route guidance to drivers as a means of reducing congestion on busy urban corridors, and lastly, we are doing very long range research to get more vehicle flow on our existing freeways, by using automation features to safely place them closer together and at higher speeds.

The main thrust I might offer regarding the right-of-way bill is that it not be limited to Maglev systems. For example, in the Las Vegas study, the French TGV Atlantique was also found to be a viable candidate for that corridor, but it needs access to the I-15 right-of-way to be cost-effective. As written, your Federal legislation could constrain a regional (California/Nevada) decision regarding technology choice in that corridor.

In addition, it is my opinion that there may be advanced highway systems that could provide greater public sector benefits providing we can install hardware along or in the roadway. If the language were broadened it would still accomplish the basic goals of providing more capacity on our existing right-of-ways and thus reduce pollution and energy consumption as well. For example, an electronic controlled, or perhaps even electrified, lane in the highway to carry twice the volume of today's traffic may prove feasible after the current round of PATH R&D and demonstrations.

What America needs is another great infusion of advanced technology as we prepare to rebuild our failing infrastructure. Now is the time to do the R&D homework so we can rebuild better and smarter. We can't afford to rebuild the old way or our operating inefficiency will drag the economy further astray. We need bold, new infrastructure for the future America.

In closing, I urge that we get transportation back on the front burner before we face more damaging national losses than the potential Maglev loss. Let's require R&D efforts to determine best how to build future transportation systems, rather than continue to buy foreign products at the cost of high technology American jobs. Let's require R&D rather than to continue to think that minor adjustments in funding or regulations will provide tomorrow's infrastructure. Federal agencies must do more to assist in the R&D leadership. Private companies and large States, even California, can't do this alone.

I thank you for your attention.

Senator MOYNIHAN. We thank you, sir. We'll get to that experience, simply the elimination in the Federal Government over three administrations, or four, three or four, if you like, of something that is, you know, elementally essential.

Mr. PARSONS. Bitter to both of us, sir.

Senator MOYNIHAN. And now Dr. Choate, our final panelist, and we welcome you to this committee, sir.

## STATEMENT OF PATRICK CHOATE, DIRECTOR OF POLICY ANALYSIS, TRW, INC.

Mr. CHOATE. Thank you very much, Mr. Chairman, Senator Graham.

I am pleased to have the opportunity to share some thoughts, and, with your permission, I also will submit my testimony for the record and briefly summarize it.

Senator MOYNIHAN. Exactly so.

Mr. CHOATE. The basic thesis that I'm offering this morning is that the American economy is an experiment in transportation. When we take a look back over the past ten years, what we see is that we've had a 25 percent increase in ton-miles of freight that have been shipped, and a 40-percent increase in passenger miles. If one takes a look further, what we see is that transportation consumes roughly 13 percent, it's 13 percent of our personal consumption. What that really means is that we're major consumers of transportation and, more importantly, when we look forward to the next 10 years, what we can anticipate is a similar increase in both passenger miles and in freight movement.

Well, when we do that, what we see is that our capacity to be able to do that effectively and to do that efficiently is threatened.

As other witnesses before this committee have testified, as a presidential commission that was initiated by the chairman reported recently, is that our roads, our bridges, our highways, our streets, our airports are deficient. They are barely able to meet the demands of the 1980's and they are certainly incapable of meeting the demand of the 21st century.

What I found interesting was the study that was done by the Transportation Systems Center, and what they attempted to measure is the cost of inaction, and the costs of inaction are very high. They report that just to permit the roads to continue in the present condition will mean a 3-percent loss, reduction in our Gross National Product, a 5-percent decline in disposable income, nearly a 3-percent decline in labor productivity in manufacturing, and a 4-percent productivity decline in the nonmanufacturing sector.

I think the point there that is clear is that a first-rate transportation system is costly, a second-rate transportation system costs even more to a society. The costs, however, are hidden.

Now, as we look towards the future, the question is, do we continue to place all of our bets in existing technology, or in refinements of technologies devised in the 19th century, where we bring those technologies to the final refinements, or do we put——

Senator MOYNIHAN. As I might say, you know, the Japanese bullet train——

Mr. CHOATE. Such as the bullet train.

Senator MOYNIHAN. Is just the last ounce you can get out of a 19th century machine.

Mr. CHOATE. The cost of taking, from 160 miles an hour to 175 miles an hour just becomes prohibitive at that point.

So the question that we are really facing is, I believe, the only choice I believe we have and what I am advocating, is to say that we need both a quantitative approach and a qualitative approach. Clearly, we need to make investments in improving the existing systems, to repair, rehabilitate, at the same time, it's necessary that we put money in new technologies.

I am an economist and not an engineer, but, as I hear the inventors, Powell and Danby, this morning, as I've talked to the chief scientists and engineers at TRW, it seems rather certain that Maglev is a good bet. If one were betting that one would see that this will be a major technology that will be deployed into the 21st century. And what's also, I think, encouraging and realistic is, I believe, what Dr. Danby indicated, is that we're at the first initial stages of a technology equivalent to the Model-T and perhaps to the woodburning steam engine. They were effective. They changed society. When we put R&D, when we have experience, it's very clear that even this technology, economically and technically feasible now, will improve over time.

It's clear that our competitors are making these investments. But as an economist, interested in the United States and the global economy, I'm also interested in the question of who's going to gain the economic benefit, not only just from the deployment of this system, but from the development, and the manufacturing, and the exports of the system.

In a very real sense, something that would be analogous would be to take a look at our aerospace industry today. Now, here's a transportation sector where the United States has made significant investments. We have a technological lead. We produce 85 percent of the commercial aircraft made in the world. That industry produces $110 billion for our economy. It produces $22 billion of export. It produces 800,000 jobs. When we take a look towards the 21st century, something comparable can be developed out of this industry. We're certainly the largest market in the world for transportation systems. It's very clear that Europe and Asia will be developing these systems.

If we can get ahead of the technologies, as you were suggesting, Mr. Chairman, and move leap-frog forward, be able to develop those technologies, to manufacture, to do the systems engineering, and to deploy, here's what we have then is a potential to create jobs, to deal with our trade balance, to be in a position to capture all of the other extra analogies that exist.

I would like to say one other point, and that was on the VCR analogy this morning. I think that we could argue that the United States semiconductor industry was put into a perilous condition in the 1970s, when the U.S. consumer electronics industry lost its prowess with television and lost the race to VCR's, because VCR's and televisions are really bundled with semiconductors in use, demand. And so, when America's semiconductor industry lost that potential, then that industry was greatly imperiled. Here is another potential in which, to take that in reverse, if we can build such a system, it would seem to me that, with the magnets and a series of other technologies, here is a series of extra analogies that can be of great benefit to dozens of linked industries.

The final point that I would say is that, it seems to me, as I hear the inventors, as I talk to other people, is that how this race is going to be determined, come out. It's not predetermined at this point. In large measure, it's going to be determined by the actions of business and government, and how the quality of their vision, and how well they're willing and able to work together. The only thing that seems to be reasonably certain at this point is that this country will have, in the 21st century, a significant Maglev system. The question, will we do it, or will others do it for us.

Senator MOYNIHAN. There you are. There you are, Dr. Choate.

May I make a point before turning to my colleague, and then asking you just to talk among yourselves. On the role of government, you mentioned aerospace. And you may have seen a list recently published of our exports to Japan, and, you know, what we sell to Japan is logs, and rocks, and airplanes. Now, it's happened that I was in here in Washington in the Kennedy administration, and President Johnson was chairman of the Space Committee, and the principal concern was the SST. We kept meeting, and I would, from time to time, represent the Department of Labor at these meetings.

One thing just struck me at the time, and I hadn't thought about it until Dr. Choate spoke. Why was there such a great discussion of whether or not to build the SST. In the end, of course, we didn't. And it went on, and on, and on, 15 years. Simple! The SST was to be the first passenger aircraft which had not been developed by the military for military uses in the first instances, after which they painted, they put nice seats in them, they put in the nice ladies that gave you hot towels, you know, and things like that. I remember very distinctly, meeting in the old EOB with Harold Brown, who was Secretary of the Air Force at the time, and he would come over with the cost estimates for making and running this system. And why did they have them? Because they, the Air Force had set out to do a supersonic transport and then said, well, you know, for the number of drops you can get aboard this thing in full battle gear, and enough ammunition to land and hold out for 48 hours, and it turns out you can only get 34 of them in this plane, and the extra 5 hours in distance didn't make up for the fact you only had a platoon at the end of the run. So they said no, it's no use to us, we need bigger. We're fast enough. We need volume. So here, does anybody want to build it for civilians?

And that's what that was all about. Every of one of those planes had a military prototype. And to act otherwise is to avoid the reality here. Or so I think.

Senator **GRAHAM**. Mr. Chairman, that latest of an extremely interesting series of historical chapters that you provided us, I might say one of the joys of being in this institution is to be a student at Pat Moynihan's seminars.

It reminds me of one of the case book of American business, and that was when the railroads were asked the question, at the beginning of this century, "What business are you in," they answered, "We're in the railroad business," failing to move to a higher level of conceptualization that they were in the transportation business, and by defining themselves narrowly, defined themselves into a static and, for most railroads, a move to a bankruptcy position. So I think we need to apply these lessons of history creatively, and not so restrain ourselves.

Having stated that, what do you think should be the Federal Government's role in creating the environment which will be most stimulative of this type of activity, given the fact that some of the types of environment which we have looked to in the past, specifically, the high linkage to military benefits, which, in addition to airplanes, your comment was the basis upon which the interstate system was constructed as a defense highway system. But assuming that's not going to be the generator of innovation in this new dimension of transportation, what do you see as the steps that the Federal Government should take in order to create the most optimum environment for the development of this and other new technology transportation systems?

Mr. **RUSH**. Senator Graham, Federal support for initial research and development certainly is something, as you and Senator Moynihan have stated, it appears we only get Federal support when it is defense-related. Here is something that is people-related certainly, and will do the most good for the most people. And the only support that was given appeared to be back in the early 1970's when that support was then removed as soon as the oil crisis seemed to have let up at the time.

Leadership in the direction of research and cooperative support for joint public-private research initiatives. Somehow or other, that has to be worked out where, if industry is a participant with government, that there are some incentives for industry to go ahead and do this. Private incentives and initiatives to effectively implement research advances. I mean, most of the advances that have occurred, in medicine, and in industry, have come out of "garage" operations and entrepreneurs such as the gentlemen sitting at this table, who had no support from the government.

But again, since it wasn't invented here, as far as the government is concerned, they have not embraced that. And that is the reason it has gone offshore and we have lost so much of our initiatives. Of course, access to existing Federal resources, such as highways, rights-of-way, crossing over our waterways without putting up all the stumbling blocks that normally you have to go through in order to get access to these rights-of-way.

So those would be my suggestions.

Senator MOYNIHAN. Dr. Danby again. Would everybody just join in. I see Mr. Parsons.

Mr. DANBY. I agree with Mr. Rush, but I would like to add a complementary aspect to that. Let's say, for the record, we were not starving inventors. We had both been supported by the United States Government throughout our careers, doing our academic research.

Senator MOYNIHAN. As best I understand the event, one of you was trying to get up to a beer party at MIT and you were stuck in front of the White Stone Bridge, right?

Mr. DANBY. That's right. But my point is, I agree with it, but only with a severe caveat. I know we're very strong in research in this country. Sometimes we don't think we are. We've been weak on follow-through. And with the consortium of government and industry on the megachip, we're waking up in that area, which is vital to defense and our future. So, yes, this needs a research element, but what it really needs, in my judgment and Jim's, is a government, various government-industrial consortium approach to actually do it. The research is, again, incrementally useful, and I am not disagreeing with that. But what is really going to move this thing is if we just don't give a bunch of academics money to go and play with it for 20 years. I exaggerate to make a point: Research is a useful contribution, but we really need to get into the business of getting our industry working to come up with new systems, obviously interacting with government, that's the nature of the problem, plus finding the money.

Senator MOYNIHAN. Well, that is going to be the purpose of the committee which you and Dr. Powell will be joint coordinators. We're gonna have a report to the President. This is what we want to do.

Mr. Parsons?

Mr. PARSONS. Yes, sir. I would like to address Senator Graham's question from my perspective when I worked in DOT from its inception. I was also the Deputy Director of the Supersonic Sonic Transport (SST) development program during some of those years, Senator Moynihan.

The enabling legislation that created DOT, specified that the Secretary has the responsibility to foster the development of transportation systems, including development as needed. That's how the SST was authorized for funding. It was a balance of trade threat. The threat wasn't the SST and the Concorde so much as what we see today, the consortium of aircraft builders abroad, who developed a new line of aircraft namely the A-300. The Concorde initiative was basically the means of getting those countries to cooperate and build these new planes.

About that same time, the White House Scientific Adviser position was abolished. To this day it's never been established. Later, in the Department of Transportation, they abolished the position of the Assistant Secretary of Transportation for Technology. That's position has never been replaced. My idea of what needs to be done, is to unravel what we did wrong here.

Until you have technology people into high levels of the administrative side of the government that understand the issues, we're talking to ourselves. And the blame is not only there. Congress has sat by and let the administrations not enforce these acts and not say anything. The High Speed Ground Act is still in existence. I was directed to write the final report for that act citing that the Department of Transportation had decided to stop funding these activities and declared unilaterally it was over in the Congress, there wasn't a peep of objection. That's why we're sitting here today wondering what happened to our high speed work.

So there's a need for somebody in this country to start putting technology back on a front burner, both in this house and down the street in the administration.

Senator MOYNIHAN. I would note that our distinguished colleague, friend, Senator Chafee, has joined us, and we've been hearing some absorbing testimony.

The two gentlemen you see in front of you are the ones who invented and published the first Maglev papers. There seems to be no doubt about it now that Florida will order a high speed system this June. The Nevada-California system is well under way. And the only technology they have available to them is the Japanese, on the one hand, the Germans on the other, and Mr. Rush, who is in charge of the Florida project, has given us an item from the Orlando Sentinel which says the "Rivals Team Up on High Speed Rail. Japanese Would Use German Trains." And our jurisdiction here is to back up the Interstate System to provide the right-of-way for this kind of transportation, which would otherwise be hugely expensive.

Senator CHAFEE. Mr. Chairman, I stagger from the mundane. I've been working on degradable six-pack holders to this high technology.

Incidentally, and if I might divert a minute, probably Senator Graham has the same question frequently asked him. What's the difference from between being Governor and in the Senate. And I think the difference is that, as Governor you see the same issues come around and around again over the course of your term. Whereas, in the Senate, you certainly find a greater variety of issues, at least I have, and here's an example of it. And then from here we'll go to the signing of the Canadian Free Trade Agreement very shortly, which I notice Senator Moynihan has his signing suit on. So I'm sure he's going.

But I confess, I know very little about Magnetically Levitated Transportation Systems, and I am delighted to have the opportunity to learn something as I pause in my efforts to get rid of plastic six-pack holders.

Thank you, Mr. Chairman.

Senator **Moynihan**. We are going to have it, but we have about 15 minutes remaining. The President has asked us to the signing of the United States-Canadian Free Trade Agreement, or our side of it. Can I ask you, and both Senator Chafee and Senator Graham, will want to have a copy, a list of the participants in the study that we now wish to go forward with. And that's a fairly compressed time. It's now October, or almost, John and I are in reelection cycles, and I know how many days to go. Do you know how many days to go? Forty-three, if you don't know.

Senator **Chafee**. There's a difference in the campaigns totally. If he has an opponent, nobody knows who it is. My situation is quite different.

Senator **Moynihan**. And your gap is widening. But I still know how many days to go.

But could you tell us what your sort of work plan is, and how we can be of help to you? And Mr. Parsons, obviously, we know, we can—the Department of Transportation still does have this responsibility and might be of some assistance. How do you mean to go ahead?

Mr. **Powell**. As you said, there is a limited time. So we felt that we would assemble a group of people who were interested, of course, and also had some background in magnetic technology, and that's what we have concentrated on. The idea is to get a detailed outline written, which has been done, and then have people start making contributions to the report, in parallel. With the contributions broken down in that way, hopefully, it will not be too great a burden on any one particular person. Those contributions will then be assembled by Gordon and I into an initial draft, which will go out and be commented on by all the members of the task force.

I'm sure there will be a lot of disagreements, and we'll have to——

Senator **Moynihan**. That's fine. We don't mind.

Mr. **Powell**. Yes. We don't mind that. And we'll have to hammer out some sort of consensus. That will probably be the hard part.

Senator **Moynihan**. We don't even need a consensus if there isn't one.

Mr. **Powell**. We'll try for a consensus, at least. And then we'll go through a second draft, and then deliver the report to you. We've broken the report up into a number of sections dealing with the importance of Maglev to the United States. That includes questions like mobility, environmental effects, competitiveness, and effects on oil imports, and so forth.

The second section will be the review of the existing technology, what has actually been done, how good is it.

The third will be a forecast of what we can see happening—we certainly don't want it in excruciating detail—but we want some sort of idea, of how much can you improve the technology, what we can forecast happening.

The next section will be, since the focus is on the Interstate Highways, a discussion of the Interstate System and how Maglev can play a role in that. What I hope, is to have several examples of how Maglev systems would look if they were applied in different areas of the country.

Senator MOYNIHAN. Well, I mean, your evidence, and Senator Chafee, you might want to hear this, since you heard an awful lot about the Shoreham nuclear reactor in this committee.

Dr. Powell suggested, if we could, a Maglev system in Long Island, which is running a round-trip distance of a hundred miles, carrying 150,000 people a year, would in one year save 8 million barrels of oil, which is equivalent to the oil needed for the generation of 600 megawatts of electricity, which is about what Shoreham will do.

Senator CHAFEE. That would be the savings from the current trains?

Mr. POWELL. Current cars, automobiles primarily.

Senator CHAFEE. Oh, and automobiles.

I was going to ask about the power requirement for the Maglev system.

Mr. POWELL. They're modest. It turns out that it depends somewhat on the kind of system—generally, the Maglev system is on the order of a few hundred kilowatts to suspend the train. Most of the power consumption is needed to overcome air drag. That's really a function of how fast you go. At 200 miles an hour it's a certain value. At 300 miles an hour, it's 4 times that value, because it goes up as the cube of the speed.

Senator MOYNIHAN. You seem to have an optimal speed around 220?

Mr. POWELL. Yes. And at those kind of speeds, traveling by Maglev will yield substantial savings over automobiles.

Senator MOYNIHAN. We were told by one of your colleagues from Argonne that a Maglev system could take one person from Chicago to Minneapolis with the energy of one gallon of gasoline.

Mr. POWELL. Yes; I would agree with that.

Senator MOYNIHAN. John.

Senator CHAFEE. It all sounds—there must be a flaw somewhere in all this.

Senator MOYNIHAN. Well, there was a flaw in the railroad. When it was started, people started——

Mr. DANBY. Levitation, per se, doesn't use any energy. It's potential energy. If you were in a tunnel, a vacuum tunnel, you could accelerate the motor, and you could brake it with another motor and put the energy back into the power line. So, as Jim said, it's basically very efficient. We have always emphasized systems that are very efficient, because we think they're most relevant, particularly in this country. You can move heavy freight very efficiently which has never been contemplated, to our knowledge, by the systems that have been developed most.

Senator CHAFEE. Are there some papers as a result of the experiments that were carried out in Colorado when the track was built there?

Mr. POWELL. Not on Maglev.

Senator MOYNIHAN. Mr. Parsons was in charge.

Mr. PARSONS. At that time, sir, this country was primarily investigating air-cushioned vehicles, very heavily so, and we only had very small efforts going on in Maglev, and these gentlemen were some of the recipients of some of the grants, as was SRI and Ford Motor Company. So we never got to serious development—the program was terminated before we ever got to any scale, other than Dr. Kolm's work, in these Maglev vehicles.

Senator Moynihan. But we do know a fair amount what the Germans and Japanese have now done.

Senator Chafee. Do they publish?

Mr. Danby. Oh, yes. Very open. And we have good communications with them.

Senator Chafee. Has anybody built one of these that is functioning?

Mr. Parsons. Yes, sir. I've ridden every one around today. I rode the one in 1979 in Munich, and that was their fourth generation system. That means they went through four cycles by 1979. Now, they're going in their seventh cycle. So they've had seven vehicles. The last three were large enough to carry people, and model 06 looked just like an airplane inside, and I rode it a year or so ago and it feels like an airplane. So this is real technology, that provide safe speedy comfort.

Senator Moynihan. And you've all been on the Japanese one.

Senator Chafee. The Japanese one, is it experimental, or is it actually carrying passengers?

Mr. Parsons. I would call it a prototype test. It's not a full scale vehicle like the German Transrapid. The ride's a little rougher, but the speed is higher. You have to wear a seat belt and put on a helmet, which are not required in the German system. It's a shorter test track. It would probably require one more development cycles, before it could go into any of our cities and convince our people. In addition, there is another Japanese system the HSST. It is being considered for a low speed demonstration in Las Vegas, also.

Mr. Danby. The Japanese are committed, apparently, to the beginning of a real system, with a 50 kilometer initial stage between two real stations, to go beyond the test track in Miyazak.

Senator Moynihan. That's a 25-mile run.

Mr. Danby. Or 30 miles.

Senator Moynihan. Thirty-mile run, yes.

Well, there you be.

Senator Graham. Mr. Chairman.

Senator Moynihan. Yes, sir.

Senator Graham. Before we adjourn, I'd like to restate my question to Mr. Choate. From the perspective of an economist, what do you think the Federal Government ought to be looking at in order to create an environment that once the technology issues have been resolved satisfactorily, will be the principal economic factors in the commercialization of that technology?

Mr. Choate. I think, as with many advance technologies in the past, such as aircraft, the computer, it will be necessary for the Federal Government to put up R&D money, in perhaps some substantial amounts.

I'd say the second thing that the Federal Government can do is, obviously, the right-of-way, because that is the major issue——

Senator Moynihan. Right-of-way.

Mr. Choate. The right-of-way.

Senator **Moynihan**. That's what this committee has. That's the hearing we're holding now.

Mr. **Choate**. Which becomes central, because that's a major deployment issue.

The third thing that I think the Federal Government can do is make this a project of national prestige. We can borrow a lesson from the French, from the Germans, and from the Japanese. On central projects, they make them projects of national prestige.

And then the fourth thing is to find the ways and means to assure timely decisions. I was very struck by an article that the Chairman wrote in the early 1980's about the cost of Westway, how those costs tripled because of delays, going from $300 million to $600 million to $1.3 billion, and eventually the project collapsed on its own weight. So it's a question of how do we find ways to make decisions quickly. Time is an important commodity in a project such as this.

Senator **Moynihan**. Just to show off a little bit in front of Danby and Powell, I think you define it a condition called entropy. Well, on that very promising, very helpful note, we want to thank you all.

These hearings will be published. You'll be getting transcripts.

Well, we very much appreciate it. We appreciate that Senator Graham was able to stay with us the whole morning, and we are here not at the end of this enterprise, but the beginning.

Thank the staff, and thank our very capable recorder.

[Whereupon, at 11:04 a.m., the subcommittee was adjourned, to reconvene at the call of the Chair.]

[Statements submitted for the record and the bill S. 2072 follows:]

# PRESENTATION OF DAVID H. RUSH
COMMISSIONER,
FLORIDA HIGH SPEED RAIL TRANSPORTATION COMMISSION
AND CHAIRMAN,
FLORIDA HIGH TECHNOLOGY AND INDUSTRY COUNCIL

## INTRODUCTION

Mr. Chairman, Senator Graham, members of the Subcommittee, I appreciate the opportunity to report on my state's efforts already underway to bring magnetically levitated train travel to Florida.

I am David H. Rush, and I'm appearing here in my capacity as a Commissioner of the Florida High Speed Rail Transportation Commission. I was appointed to this Commission and its predecessor Committee in 1982 by Gov. Bob Graham. I am just now beginning my second four year term having just been reappointed by Gov. Bob Martinez. I am also here in my capacity as Chairman of the Governor's High Technology and Industry Council which promotes and coordinates a public/private partnership of high tech education and industry in our state. I am President and CEO of two firms, ACR Electronics and Aptek Microsystems.

Florida realized the need for high tech transportation alternatives over 10 years ago when it began studying the feasibility of high speed rail including maglev.

In this paper I will detail:

I. Florida's Involvement With High Speed Rail and Magnetic Levitation Systems

II. Florida's Assessment of Magnetic Levitation Benefits

III. The Need for International and Joint
Public-Private Research Initiatives and the
Leadership Role for the Federal Government

## I. FLORIDA'S INVOLVEMENT WITH HIGH SPEED RAIL AND MAGNETIC LEVITATION SYSTEMS

In 1983 the Florida High Speed Rail Committee issued a Request for Expressions of Interest to the U.S. and international market to build a high speed rail system in Florida.

Responses from six groups included both high speed rail and maglev interests.

This committee also commissioned a $500,000 study financed by the Federal Railroad Administration to investigate the feasibility of constructing a high speed rail system across Florida.

It included a review of the economic, engineering, and technological feasibility of a state wide high speed rail and maglev train systems.

Passage of the 1984 Florida High Speed Rail Act created the High Speed Rail Transportation Commission and authorized it to seek high speed rail applicants, establish application criteria and award a franchise.

As part of the implementation of the Act, the Commission visited Japan, France and Canada to review the various high speed transportation technologies. We rode several systems during these visits, including the JNR Mag Lev system at the Miyazaki Test Track in Southern Japan. I also studied the HSST maglev system in Japan and rode the system as the Commission's representative while visiting the 1987 World Expo in Vancouver, Canada where the HSST was on display.

Our Commission staff has also visited the German maglev system in Emsland, West Germany, and we are conducting a thorough study of this technology.

While the Act anticipated both maglev applicants and high speed rail applicants, the maglev industry determined that the technology was not feasible at that time for a statewide system; therefore, no maglev proposals were submitted.

A second project was added with the passage of the 1988 Magnetic Levitation Demonstration Project Act. This act directs the Commission to:

- Issue a Request for Applications (RFA) that outlines the technical, financial, and environmental considerations that the potential maglev builder must address in its proposal.
- Establish a procedure for assessing the maglev technologies that are proposed. Among the areas the Commission will consider are:
    (1) Operational safety
    (2) Any affects of magnetic fields
    (3) Financial feasibility and service levels
- Select the proposal that best meets the criteria set forth in the Act which can demonstrate that a high tech maglev system can operate in a real world revenue service environment.

The maglev system must be built and operated solely with private funds and passenger revenues.

The Commission has been actively implementing these provisions, and is well ahead of schedule. The calendar for the project is as follows:

- Two weeks ago the Commission formally adopted a draft Request For Applications (RFA) and rules.
- December 1988: The Commission will formally issue the Maglev Demonstration Project Request for Applications.
- March 1989: Applicants will submit their proposals and a $500,000 application fee.

  June 1989: The Commission will select one applicant for certification.
- April 1990: The Florida Governor and Cabinet will issue a Final Order certifying the applicant.

This will allow the applicant to begin construction one year from this spring, and so will begin the first commercial application of high speed magnetic levitation in this country and perhaps in the world.

Four maglev technology companies have expressed an active interest in competing for maglev project certification. They are:

1. JR MAGLEV. This system was developed by the Japanese National Railroads, supported by the Japanese Government, beginning in the mid-1970's. Several prototype vehicles have been tested on a 7.0 km (4.3 mile) test track at Miyazaki in Southern Japan. This electrodynamic system uses cryogenic cooling to create superconducting magnetic forces that lift and propel the train. The vehicles have operated at speeds up to 400 km/hr (248 mph).

2. HSST MAG LEV. This is an electromagnetic or magnetic attractive force prototype developed initially by Japan Airlines (JAL) to serve as high speed ground transportation between Tokyo and Narita Airport. HSST has defined three maglev systems for different transportation markets:

   a) Low speed urban system (up to 100 km/hr) (62mph)
   b) Intermediate speed system (200 km/hr) (124 mph)
   c) High speed intercity concept (400 km/hr) (248 mph)

   These systems have not been tested at full prototype levels as yet.

3. GERMAN TRANSRAPID. Another system using attractive electro magnetic concept is the German Transrapid currently operating on a 28 mile test track in Emsland, West Germany. It has operated at speeds in excess of 400 km/hr (248 mph). West Germany recently announced plans for the deployment of the Transrapid between Hamburg and Hannover.

Another technology company interested in the Florida project is All American Magneplane, although this system is a number of years away from commercial availability. The original magneplane concept was patented in 1970 by researchers at MIT. In 1974 sponsored by the National Science Foundation and an industrial consortium a 1/25 scale model and 400 ft guideway were constructed and achieved speeds of 56 mph.

## II. FLORIDA'S ASSESSMENT OF MAGLEV BENEFITS

Florida, like America's other major urbanizing states, is facing crushing increases in demand for transportation infrastructure. This demand, when combined with serious constraints on both our budget and physical capacity to fulfill needed airport and roadway expansions, is one of the most serious issues we collectively face. Maglev may offer a viable alternative to help address these ever-increasing demands to be met with shrinking resources.

A recent study in Florida examined state public infrastructure demands and estimated that the cost for the next ten years for future growth alone will exceed $53 billion. Transportation comprises the lions share of that demand.

Another Florida DOT study that measures traffic volume by comparing the number of cars to paved miles in Florida was released this month. Vehicles per highway mile in Florida have increased by fifty per cent in the last eight years alone. For every paved mile in the state eight years ago, there were two cars on the road. Now there are three. Construction cannot keep up with demand.

Increases in airline passenger arrivals and departures show the same story. Projections for exceeding capacity at every major urban airport in the state are becoming routine. Expected increases in passenger delay are predicted to increase with no end in sight.

Maglev with its very high potential passenger capacity operating on a relatively narrow corridor holds promise for relieving some of this intense and building pressure.

The 1984 high speed rail feasibility study identified a wide range of economic, environmental, growth management and transportation benefits for a statewide system.

ENVIRONMENTAL BENEFITS

Air Quality - In comparison with automobiles, maglev will have an overall positive impact on air pollution, due to a reduction in carbon monoxide, hydrocarbons, total suspended particulates and nitrous oxide emissions. If the expected ridership for a Miami-Tampa system were diverted from automobiles, the change in tons/year of emissions are estimated to be:

| Air Pollutant | Tons/Year |
|---|---|
| Hydrocarbons | - 829 |
| Carbon Monoxide | - 7276 |
| Nitrous Oxides | - 561 |
| TSP | - 95 |
| Sulfur | + 993 |

Sulfur emission estimates are higher since electrical generating stations, which supply the maglev's power, emit much larger quantities of sulfur compounds than cars. However, desulfurization technologies for power plants are continuously improving, and thus will continue to reduce the differential. The overall emissions are less for the other pollutants, since power plants are "cleaner" for those categories than automobiles.

Water quality - The water quality benefits of maglev compared to other transportation modes will depend in large part on whether co-location with other rights-of-way is allowed. The main impact on water quality from maglev would arise from construction of the guideway on a new ground-level base, or from construction-related access roads for an elevated guideway.

If maglev is built on existing rights-of-way as proposed in this legislation, fewer roads are needed to support automotive traffic; therefore, a net benefit and enhancement to water quality will result relative to road construction for comparable ridership.

Maglev guideways can be built from the "top-out"; therefore each guideway support can be used as a means to cantilever out to the next support. This would eliminate the need for heavy construction vehicles or roadbases in wetlands. Again, the use of existing rights-of-way, will greatly decrease the water quality-related impact of maglev.

Noise - Maglev is much quieter than other surface transportation modes because it is frictionless. This is of great benefit in urbanized areas or in sensitive wildlife habitat.

Wildlife & Habitat - Maglev systems are elevated; therefore, there is minimal danger to sensitive wildlife and their habitat. While there are several potential concerns, such as the "startle" effect of a vehicle traveling at speeds of 300 mph and the accompanying noise, co-location with existing highway projects would lessen that impact.

Magnetic & Electric Fields - The fields generated by the repulsion (electrodynamic) or attraction (electromagnetic) systems are unique to maglev as a transportation mode. They pose some complex issues which further research will help resolve.

The electromagnetic levitation systems do not produce intense direct current (DC) fields. The electrodynamic systems produce stronger fields, using direct current to create high static fields in unshielded areas. Fields stronger than 10 Gauss can interfere with the operation of some cardiac pacemakers.

Fields only slightly higher than 20 Gauss will interfere with devices which might be brought on-board such as magnetic bubble memory portable computers, cameras, watches, and bankcards. Health implications for AC fields are not conclusive to date, while obvious risks for high DC fields are fairly well understood.

Shielding the vehicle will reduce the DC field levels of the interior to 10 Gauss levels or below. This shielding will, however, affect the weight of the vehicle and thus the energy needed to move it. The fiscal tradeoffs of shielding versus environmental risk are quite complex and should receive considerable attention in any future research. Research into light-weight shielding, e.g. thin-film cryogenically cooled shielding, offers great promise for reducing potential environmental risk.

Energy Efficiency - Maglev has marked benefits in the area of energy conservation. If one compares passenger mile energy needs of maglev systems to other transportation modes, maglev:

- uses one fifth the energy of an automobile
- uses one tenth the energy of a Boeing 727 jet
- has a slightly higher power consumption rate than other rail systems

Reduction in vehicle weight will improve these comparisons further for both the electrodynamic and electromagnetic systems. Advancements in superconductivity could significantly improve energy efficiency in the electrodynamic system. Use of maglev will further America's goal of becoming energy independent.

## TRANSPORTATION AND INFRASTRUCTURE

Maglev would be complementary to other modes of travel in Florida by serving predominantly the intermediate haul markets, while the automobile and airplane would dominate the short and long haul markets respectively.

Between 2.8 and 5.6 million long distance passengers (85 miles or greater) would be safely, efficiently and swiftly transported per year in Florida and a considerable number of additional passengers will be transported shorter distances.

Construction of a maglev system could save millions of public sector dollars in highway construction. For example, the Florida DOT estimated that $925 million in highway construction costs could be saved if a statewide maglev system were built.

## EMPLOYMENT AND INCOME

Income is expected to increase by $800 million from construction; and thereafter, $700 million from system operation. Increases in tourism are expected to add $17 billion.

Employment will increase by 7,500 jobs for each of the six years of construction, then by 1,500 jobs per year thereafter for operation and maintenance. In addition 37,000 jobs per year will be added in the service/tourist sector of our economy.

## ECONOMIC

Over $2 billion in user benefits will accrue from savings in vehicle operating costs, accident costs and travel time. There will also be a reduction in oil consumption thereby reducing our dependence on foreign oil and the foreign trade balance deficit.

Maglev industry attracts other high tech business and will broaden Florida's economic base.

## III. THE NEED FOR INTERNATIONAL AND JOINT PUBLIC-PRIVATE RESEARCH INITIATIVES AND THE LEADERSHIP ROLE OF THE FEDERAL GOVERNMENT

The Federal Government has provided vital leadership to many of this century's most significant high tech research advances.

Your proposed legislation tracks these successes where it provides for:

1. Federal support for initial research and development
2. Leadership on the direction of research and cooperative support for joint public-private research initiatives.
3. Private incentives and initiatives to effectively implement research advances.
4. Access to existing Federal resources-highway rights-of-way

We believe this Federal leadership could extend even further by:

1. Providing access to and right to traverse other existing publicly owned rights-of-way and public lands.
2. Planning for multiple use options in future expansion and design decisions of future federal corridor projects.
3. Providing other financial incentives such as tax benefits for research efforts.
4. Providing financial support for American research conditioned on building from existing advances achieved elsewhere throughout the world.

5. Affirming the need for a joint public-private international partnership.

## RESEARCH AND DEVELOPMENT BENEFITS AND TECHNOLOGICAL LEAP FROGGING

To borrow a concept from John Riley, Federal Railroad Administrator, we must build on hard won advances achieved here and elsewhere in the world and not recreate the wheel. We need not and must not re-expend those enormous front end start up costs incurred by other governmental and private researchers elsewhere in the world to relearn what they know.

The project we are actively pursuing in Florida is intended to provide a vital link in this technology transfer and capture concept. We very much believe examining a magnetic levitation project is a major step in the right direction to evaluate economics, service levels, environmental and technological benefits maglev systems may have for the United States. Our project will help:

- Prove operational reliability
- Demonstrate technological operability in a revenue setting
- Help enhance Federal research agendas by providing an operational system for testing and evaluating public acceptance

Private sector research time horizons are often short run, given the risks of rapid changes and sudden obsolescence inherent in technology advances. Frequently where the risks and costs are high but the long run rewards to society (both public and private sector) are substantially higher, governmental support for research is essential.

Considerable research suggests that "pluralistic" R&D efforts are most productive. These efforts involve a large number of independent private sector, university and governmental laboratories exploring avenues of technological advances and applications.

This should be the focus of future advances in magnetic levitation research in this country. This is the proven path in both Japan and Germany where each nation has expended approximately a billion dollars in development of electrodynamic and electromagnetic propulsion systems. These advances should help research in this country.

## CONCLUSION

Revolutionary technological developments of the past few decades include the great advances in the areas of computer hardware and software, developments of lasers, robotics, bio-medical and energy advances to name but a few.

As in other areas of technological development electromagnetic research in this country will stimulate economic development, enhance the nation's productivity and improve the very quality of our life.

For these reasons, we in Florida support the concepts in the Moynihan legislation and the Federal initiatives it represents.

## TESTIMONY OF ROBERT E. PARSONS

before the

**Subcommittee on Water Resources, Transportation and Infrastructure**

**of the United States Senate Committee on**

**Environment and Public Works**

September 28, 1988

Mr. Chairman and members of the Subcommittee.

It is my pleasure to appear before you today. I am Robert E. Parsons of Walnut Creek, California. I have been involved with advanced transportation research and development all of my professional life.

Your bills address very important issues that have bothered me during most of my career at DOT. Congratulations for your wisdom and the courage to give new innovative transportation systems at least a chance of being considered as part of the solution to the country's pollution, traffic congestion, energy, and safety problems.

As this committee knows, advanced ground transportation has not been given an even playing field when it comes to government support. Should a magnetic levitated (maglev) vehicle, high speed rail or other advanced ground system be economically and socially attractive for implementation there is no where to go for federal assistance as there is for a highway expansion or new airport. Your bill, S. 2072 addresses this issue, at least for maglev systems. My main suggestion would be to broaden its scope to include other advanced guided ground systems, and I will support this recommendation later.

I also agree with the underlying thrust of your other bill, SB 1794 - America has lost her technology leadership. Here too, I suggest that the heart of the problem be addressed rather than just reactivating superconducting maglev R&D.

What you have so eloquently highlight as the maglev technology situation represents "just the tip of the iceberg" of lost transportation opportunities by this country in the last decade or so.

When I entered the transportation field, the United States dominated all modes, not only did we operate the best systems, but our manufactured transportation products were competitive worldwide. Now, as we all know too well, the U.S. Transportation supply industry is competitive internationally primarily in large transport aircraft. We have lost most of the others to foreign firms.

We are falling further behind very rapidly on several significant fronts. Today, European automakers and their governments plan to spend $700 million in the Prometheus program alone over the next seven years to design the cars and roads of the future, and Japan plans to install an Advanced Mobile Traffic Information and Communication System in Tokyo that will provide drivers with route information, traffic congestion predictions, travel aid information (i.e.parking availability, hospitals) and is also investigating the next high tech industry - one pertaining to the Intelligent Vehicle/Highway system. Experts say this market will dwarf the current P.C. markets, in terms of computer content. It will also impact our infrastructures. -

Since retirement from the federal government, I have been managing research for the Institute of Transportation Studies at the University of California at Berkeley, except for the leave of absence to manage the Las Vegas maglev study. Currently, I am Director of the Program on Advanced Technology for the Highway (PATH), which is a bold California Department of Transportation initiative to address urban highway congestion, safety, pollution and energy use. Specifically, PATH is investigating a unique non-contact electrified roadway propulsion system for use on the most congested sections of our freeways. We also plan to demonstrate the value of on-board navigation devices on cars that permit two way communication with freeway electronic control centers to provide route guidance to drivers as a means of reducing congestion on busy urban corridors and lastly, we are doing research to get more vehicle flow on our existing urban freeways - by using automation features to safely place them closer together at higher average speeds. These potential, new electronic lanes should also be able to use existing federal aid R-O-W's.

This loss of leadership in U.S. transportation technology deeply concerns me. Unfortunately, based on my experience I find much of the fault lies with the Government. Most agree that industry must look at the bottom line and thus they tend to be short term investors (although foreign industries find it profitable to invest in the longer term), but almost all say the government must provide the long range, high risk investments. In transportation this just hasn't been the case in the last ten years. DOT tends to think in very short range R&D terms. I basically left federal service because I couldn't support policies that said we would be second best in transportation and let the foreign countries develop systems that we could implement. Budget people actually counted our savings from such policies!

I simply can't buy this, for in my lifetime much of what we as Americans enjoy came directly out of transportation developments, all fostered by our government; the trains, the automobile/road system, river and port improvements, the interstate system, the airplane, the system of airports, etc. Why then, is now the time to say no government support, when most of the systems need replacing.

What has changed? Transportation still accounts for about one fifth of our GNP, but we push its future off on others. Our transportation system and ability to supply products that operate on these systems is vital to our economy. Those who think a US company can invest $500 million or more to compete with Japan or Germany for maglev business are dreaming, we will simply lose these markets and then be forced to import more high tech products.

The committee staff asked that I present my views on why we abandoned the maglev R&D and the general decline in DOT R&D. Having read the record of the February 15, 1988 hearing of this committee, I might be able to clarify some of the misconceptions.

During the early seventies, the DOT/FRA were worrying about a national railroad system that was in very serious financial straits. The overriding emphasis was on restructuring and assisting the freight railroads to stand on their own. Research was deemphasized across the board, with the exception of safety work. The OMB decision, which was supported by DOT policy makers, was to terminate all advanced ground systems work. At that time, the U.S. was ahead in linear induction motors and some other aspects of advanced ground systems. The promising maglev investigations were also terminated, those funded by FRA and NSF.

During most of my watch as Associate Administrator of R&D at FRA, there were no higher echelon technical staff to review or appeal these policy decisions. Technical decisions were being made by non technical persons. During the Nixon Administration, the White House Chief Scientist position was abolished and to this day has not be reestablished. Under the Carter Administration, Transportation Secretary Adams, abolished the position of Assistant Secretary for Systems Engineering and Technology, resulting in a budget review process dominated by budget and political persons. In my opinion many technical issues were either misunderstood or not even considered, particularly those having future trade balance consequences.

For example, when ordered to cut all FRA advanced R&D, I argued as hard as I could in this environment, but could not prevail. It took all of my persuasive abilities to retain a $100,000 per year line item to assess the foreign advanced technology activities and prepare a yearly report for Congressional and Administration review to determine if other countries were exploiting our absence. Even this meager monitoring effort was cut from the FRA budgets once I left to go the the Department of Commerce.

The timing of my move to Commerce was prompted when the FRA administrator directed me to terminate all non-safety R&D, even that cooperative R&D with industry to improve product performance. I argued, in vain, that assisting the rail suppliers to market better products aided the financially weak railroads. In the ensuing arguments, he suggested that if balance of trade concerned me that much, then perhaps I should move to Commerce, since DOT wasn't concerned about trade problems. In fact, during that time period DOT was encouraging foreign R&D investments on the premise that it would save the U.S. government resources for near term fixes to the transportation system.

At the Commerce Department, Assistant Secretary for Productivity, Innovation and Technology, Jordan Baruch asked that I join his team to try to improve the productivity and competitive position of U.S. industrial sectors, particularly those that were important regarding trade balances. Several major Congressional and Administration initiatives were undertaken, including the Stevenson-Wyler Technology Innovation Act of 1980. My organization (Office of Strategy and Evaluation) was to establish the means to assess international competitiveness in key trade sensitive industries (semiconductors, transportation) and develop technology policy options to assist U.S. firms become more productive and competitive.

Shortly after the change of administrations, this activity was abolished on the premise that industry knows best how to stay competitive in world markets. After laying off, newly hired bright, young engineers and policy analysts, I managed to have my job abolished and retired early. I could take no more of the Government's yo-yo technology policies from one administration to the next. Unfortunately, the government lost many very good technical people during this turmoil and our trade situation has now turned drastic.

After that sad commentary, I offer a few thoughts on how one might reverse the downward spiral in U.S. transportation technology. Eventually we must address all U.S. technology, as we are losing or have already lost many high-tech markets, not only those in transportation.

First, there is a need for strong technology input and understanding of these issues at the White House. We also need strong technology advice at the secretarial level of key civilian departments. I find it obscene for the Department of Transportation - a department so dependent on technology - not to have an assistant secretary for technology. Lawyers, economists, and accountants, no matter how good they are, must have qualified technology input to transportation policy, regulations and programs of the modal administrations. It requires a qualified staff.

Congress must pressure these departments to comply with congressional directions. For example, the DOT unilaterally stopped all advanced technology research and development required under the High Speed Ground Act of 1965, by writing the 10th annual report and unilaterally declared that the high speed effort was over and that the 10th report would be the last one under the act.

Congress did not react, so today we are discussing why the U.S. has no High Speed Ground systems to offer to American cities and states that need them. There are many to blame.

Now I will address the need for and importance of the use of rights-of-ways along Federal-aid highways for advanced transportation systems aimed to relieve traffic congestion and ease pollution problems, based on my experience as manager of the Las Vegas - Southern California Super Speed Train Development Study and Director of the Program on Advanced Technology for the Highway.

In 1984 I worked as manager of the Phase II Las Vegas - Southern California Super Speed Train Feasibility Study. The study was a two year, in depth investigation of the market potential and the technology, social, financial, environmental issues bearing on implementation of a 250 mph system. I coordinated the work of five other study contractors. Three maglev technologies were considered and the advanced "Atlantique TGV" was also considered due to its 185 mph cruise speed and its claimed 5% climbing ability. In addition, several American concepts were evaluated, but none met the City's criteria of having been in large scale testing or service. Since there is no federal R&D or testing of the advanced systems, cities or states wishing to implement a new system, must have some degree of confidence in the system concept in order to gain private financing.

During our study several potential route alignments were considered, but for environmental and cost reasons the existing highway R-O-W, Interstate 15, was deemed best. Our study contractors quantified the benefits of switching a third or more of future I-15 motorists to the super speed train and the impacts were impressive. In addition to the prevention of many auto related accidents and deaths and injuries, highway maintenance costs would be reduced and a planned third lane in each direction of I-15 between Victorville and Barstow, California may be delayed or possibly not needed at all. The added costs of R-O-W to place the Super Speed Train (SST) elevated structure along the Interstate shoulders was very small since California had either purchased extra land for the planned future expansions or had options to buy the land. In Nevada there was no problem, since no development was planned near the Interstate.

Our financial study contractor had preliminary discussions with both state and federal personnel and deemed that once we convinced the state highway directors of the highway benefits of diversion of major auto traffic to the train and the fact that our construction and maintenance plans were so structured so as not to impact highway maintenance, the SST would be granted use of the R-O-W. Then both state highway directors must convince their governors to request that the Federal Highway Administrator go along with this use of the public R-O-W. Needles to say, there are a lot of uncertainties in the process I have outlined and experience has shown that no two states approach a similar problem in a uniform manner. To remover this uncertainty, that could affect the ability to raise risk capital for these innovative systems, there is a real need to define the process to gain use of these valuable public access routes for advanced systems. Your bill addresses this need for some advanced systems.

The main comment I might offer regarding the R-O-W bill, based on my perspective as manager of the Las Vegas study and as the current PATH Director, is that it not be limited to maglev systems. For example, in the Las Vegas study, the French TVG Atlantique was found to be an acceptable candidate for that corridor, but needs access to the I 15 R-O-W to be cost effective. As written, this federal legislation could constrain a regional decision regarding technology choice in that corridor.

In addition, it is my opinion that there may be advanced highway systems that could provide great public sector benefits providing we can install electronics along or in the roadway. If the language were broadened it would still accomplish the basic goals of providing more capacity on our present highway R-O-W and thus reduce pollution and energy consumption as well. For example an electronically controlled (or perhaps electrified) lane in the highway to carry twice the volume of today's traffic may prove feasible after the current round of PATH R&D and demonstrations. Therefore, I suggest the bill be broadened to include all advanced guided ground transportation systems.

What America really needs is another great infusion of advanced technology as we prepare to rebuild our failing infrastructure. Now is the time to do the R&D homework so we can rebuild better and smarter. We can't afford to rebuild in the old way or our operating inefficiency will drag the economy further astray. We need new, bold infrastructure for the future America.

In closing I urge that now is the time to get transportation back on the front burner before we face more damaging national losses than the potential maglev lost. Let's require R&D to determine best how to build future transportation systems, rather than continue to buy foreign products at the cost of high technology jobs. Let's require R&D rather than to continue to think that minor adjustments in funding and regulations will provide tomorrow's infrastructure.

I thank you for your attention.

Testimony
of

Pat Choate
Vice President of Policy Analysis
TRW Inc.

Before

United States Senate
Subcommittee on Water Resources, Transportation
and Infrastructure
Committee on Enviroment and Public Works
Washington D.C.
September 29, 1988

Mr. Chairman and Members of the Committee:

I am pleased to have the opportunity to share some thoughts with you this morning about the condition of America's transportation system and the many exciting possibilities offered by magnetic levitation transport systems. In fairness to you and my employer, I want to note that any views I offer today are my own and not necessarily those of TRW.

## An Experiment in Transportation

The American economy is an experiment in transportation. Last year alone, the nation itself moved more than 2.5 trillion ton-miles of freight, up 25 percent from a decade ago. America's transporters logged more than 1.9 billion passenger miles, up 40 percent in the same period. The $800 billion outlays on transportation services this year represents more than 13 percent of our personal consumption.

Our ability to quickly and economically move such large numbers of resources, people, and goods over vast distances has long been at the heart of our economic prowess.

Now that capacity is threatened. As previous witnesses before this committee and a Presidential commission have documented, America has not built a major airport in more than a decade. Our elaborate system of roads, bridges, and streets is unable to meet today's demands, let alone those of the 21st century.

The costs of this underinvestment are staggering. Economic studies prepared by the Transportation Systems Center indicate that, if the present decline of the nation's highways continues, the U.S. will suffer by 1995 a 3 percent reduction in the Gross National Product; a 5 percent decline in disposal income, nearly a 3 percent decline in labor productivity in manufacturing, and a 4 percent productivity decline in the non-manufacturing sector. This is only a partial accounting.

Clearly, investments must be made in our nation's transportation systems, perhaps at twice current levels. Please note, I said transportation systems and did not single out rail, highway, or air modes.

The question we face, however, is whether to place all our bets on current technology, much of which represents final refinements of advances made in the 19th century or whether we should instead invest some of our limited funds in the technologies of the 21st century. The latter is the only economic choice.

Of America's investment choices, Magnetic Levitation High Speed Transportation Systems (MAGLEV) seem one of our best bets. As previous witnesses before this committee have testified, the first generation of this technology already exists. As with the Model T and the first generation wood burning steam locomotives, it is primitive in comparison of what is possible.

What is clear, however is the governments of Japan and the Federal Republic of Germany, moreover, are making significant investments -- perhaps more than $1 billion combined -- to refine this technology and prepare it for commercial service. Once the technology reaches that point, we can be certain it will be deployed within the United States, the world's largest consumer of transportation services.

What is far less certain is whether those systems will be developed in other countries or here. Will MAGLEV be another technology like Video Cassette Recorders (VCRs) that were invited here, developed and produced elsewhere and imported back into the United States?

Which nation will gain the benefits of the technology and know-how that are sure to be created as MAGLEV is refined and produced for world markets? Which nation will have the jobs? Which will realize the profits? Which will ship the exports?

What is happening in the Aerospace sector of our economy represents the possibilities for MAGLEV in the 21st century. This year the value of aerospace production will exceed $110 billion. The value of exports will be more than $22 billion. Total employment in the design, production, and distribution of this equipment will exceed 836,000.

The introduction of technologies that can speed the movement of freight and people at 300 miles per hour offers similar possibilities. Again the question is will it be our nation or one of our growing list of competitor countries that seizes this opportunity for the future?

The answer to this and the other questions I raise are not pre-determined. Rather, they are dependent on what is done by American government and business. As with many other advanced technologies that have changed work and life in the 20th century, a partnership between government and business will be required if America is to capture the benefit of MAGLEV.

Government is able now to provide one element of that partnership -- use of the Interstate Highway System right-of-ways.

As it did in the early stages with computers, jet aircraft and advanced agricultural production techniques, government funds for research and development will also be needed.

Business requires an environment where long-term funds can be committed to the development of key commercial technologies. In the final analysis this means reducing the pressures for quick results and short-term earnings.

Both government and business require a vision of what is but possible and likely. I applaud this committee for its leadership in helping the nation see this exciting new opporuntity.

Thank you.

# Testimony Before the Subcommittee on Water Resources, Transportation and Infrastructure on Issues Related to the Development of Magnetically Levitated Transportation Systems Along the Federal Highway Rights of Way

by
Arden L. Bement, Jr.
Vice President, Technical Resources, TRW Inc.
September 28, 1988

Mr. Chairman and Members of the Committee:

I am honored to have this opportunity to give testimony on issues related to the development of magnetically levitated transportation systems along the Federal highway rights-of-way. Since the greater part of my professional experience has been in research and development and the management of technology, I wish to limit my remarks to technology, technology application, and technology policy. Also, I wish to stress that the views I bring to you this afternoon are my own.

## A. Magnetically Levitated Transportation in the Context of Global Technology Competitiveness

Before addressing specific issues concerning magnetically levitated transportation, I wish to first put the problems facing this technology in the context of problems facing other important emerging technologies that are critical to the nation's future economic development and the quality of life of our citizens, but in which the United States is currently lagging the rest of the world, especially Japan. Here, I am referring to such technologies as photonics, high resolution television, high temperature superconductors, sub-micron commercial integrated circuits, and high-performance ceramics. In almost all these technology fields, United States scientists and engineers have made substantial contributions at the seminal research and development stage; however, our public and private sectors have been unable to carry out the sustained, systematic engineering development work necessary to bring advanced products into the world marketplace.

I believe the reason for this is twofold. On the one hand, government support for civilian research and development has retrenched to the support of basic research only, leaving advanced development and commercialization to the private sector. However, the high cost of capital in the United States has forced U.S. industry to focus its research and development efforts to those technological developments that show promise of market introduction within a time span of two to five years. Thus, much of the new technology developments in the United States are being focused on those markets which offer relatively short product turnaround cycles, such as computers and cycles, such as computers and software, or those developments which have an inherently short time from scientific conception to product definition, as in the case of many new products emerging in the field of biotechnology. For new products based on the longer-term sustained development periods required to achieve technological risk reduction and systems integration, United States industry is losing out to our foreign competitors. Japanese industries, for example, with their low cost of capital can afford to make much longer-range investments with the expectation of achieving a return on investment based on discounted cash flow.

It is in this middle ground of longer-term, sustained, technological risk reduction, lying between the basic research stage and commercial product development, the "so-called" pre-competitive stage, that we lack clear cut government policies for defining the relative roles of government and industry for keeping the United States competitive in critical, emerging technologies for global markets without doing harm to our healthy innovative environment and without involving government in commercial activity for which it is not equipped to do..

To lose out on too many of these critical new technologies could foreclose on our national goal of being a world leader in science and technology. Furthermore, further erosion in our technological leadership could lead to additional serious erosion in our standard of living and economic potential.

To lose too many events in the world's technological Olympics can lead to serious national consequences. In some cases, U.S. industry is already in a position of having to adopt "fast follower" strategies in acquiring technologies abroad for new product developments. During the earlier part of this century, just prior to and after World War I, when most new technologies were developed abroad, fast follower strategies were paramount in our rapid industrial growth. During that era we controlled our own domestic marketplace and were able to capitalize on national preferences and efficient trans-continental transportation and distribution networks. We were the world's champions at imitation, a distinction we subsequently relinquished to the Japanese. Today, however, our domestic marketplace is in reality a global marketplace, and dramatic improvements in transportation and communications technologies have now made the United States an integral part of the "global village". Our national preferences for product styling and performance characteristics have now converged to international standards, leaving less room for product differentiation. Consequently, the advantages of the leader versus the fast follower in competing for U.S. markets has dramatically increased.

It is not my purpose for this hearing to go into these issues in any further detail, or to presume to suggest solutions. I do, nevertheless, wish to draw the committee's attention to these problems which I believe have been largely responsible for the hiatus that has occurred since the late 1970's in sustaining vigorous development programs in most of our civilian technologies.

Unfortunately, magnetically levitated transportation technology, in which the U.S. enjoyed a clear lead in the 1970's has also fallen into this gap. Therefore, I see the issues facing the committee in this field of technology as a subset of much broader issues facing the Federal government in setting the policies needed in a budget-constrained environment for supporting commercial technologies in the national interest.

### B. Systems Issues for Magnetically Levitated Transportation

In my continuing remarks I wish to focus on issues dealing with technology, systems development, and public safety. Previous excellent testimony given before this Subcommittee by Dr. James R. Powell and Dr. Gordon Danby of the Brookhaven National Laboratory makes it unnecessary for me to dwell on the technical details of magnetic levitation high-speed transportation.

Clearly, important developments in superconducting power equipment sponsored by the DoE, DoD, and NSF and conducted at such major laboratories as Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Livermore Laboratory, Lawrence Berkeley Laboratory, the Naval Research Laboratory and MIT, have given the United States a substantial head start on the base superconducting power technologies required for such transportation systems. Furthermore, the application of high-temperature superconductors to these systems may afford further improvements in performance, weight reduction, and system costs; however, the engineering assessments studies conducted to date leave many unanswered questions concerning these prospects. Nevertheless, I believe that if we were to restart a national program in developing this mode of transportation, the United States scientific and engineering community could catch up relatively quickly with development efforts in Japan and West Germany.

I see the more important questions concerning this mode of transportation having to do with public need, acceptance, and safety perception. It seems unlikely to me that the average rider will readily opt for a ground transportation option over air travel if the scenery is passing by at 440 ft. per second, equivalent to a speed of 300 miles per hour. While such speeds are non-threatening to the average rider in high altitude aircraft or perhaps traversing deserts where the dominant features are hundreds of miles distant, the perception of speed would be highly intensified with scenes at closer range and having much higher feature densities. It seems reasonable to assume, therefore, that the public would wish to approach such high speeds after years of travel experience and proven system safety performance. Such a maturing period would require as many as 10 to 20 years or more of steady development and systems engineering.

Since system applications and overall first investment costs will be highly sensitive to inter-terminal spacings, total system passenger loadings, and elapsed transit times, the transportation modes to which magnetic levitation transportation could be viably applied during its maturing period are likely to be considerably different than the modes identified for end state capabilities involving very high speeds. Therefore, a systematic program of transportation network and systems engineering assessment studies sponsored by the

Department of Transportation would be appropriate before making early decisions or judgments on the long-term viability of this technology. Furthermore, since meaningful returns for private sector investment are likely to be achieved only at near-end state performance characteristics, an extended period of public sector investment by Federal, State and local governments will be required to attract private sector investments at the appropriate stage of technological risk reduction. In this regard, systems objectives and capabilities that best provide services to these governmental units as a means of justifying investment participation in the early developmental and operational stages would be highly desirable.

Some of the greater technological challenges are likely to be associated with adaptive suspension systems that will provide the smoothest possible ride under rapidly varying forces and which instill a sense of comfort to the rider at very high speeds. Safety systems which control entry and exit from the main line, control the spacing among transportation units, assure collision avoidance, and guard against upset conditions which might arise from weather extremes and inadvertent or intentional tampering will have to be highly sophisticated and guarantee extremely low probabilities of failure. Such systems will require near-zero chance of human error, appropriate redundancy, and minimal common-mode failures. The technical disciplines needed to design and test systems with such highly sophisticated engineered safeguards are still emerging.

From the above considerations, it seems highly likely that initial magnetically levitated transportation systems brought into commercial service will operate at relatively low speeds of 60 to 150 miles per hour, and may be limited to relatively short distances because of rider preferences for other modes of transportation for trips requiring longer times and longer distances. Nevertheless, these limitations still leave open a rich variety of possible applications to reduce the growing congestion at the nation's major airports and urban highway networks. Such possibilities include providing express shunts across beltways, feeder spokes to transcontinental and international airports, and commuter lines feeding major cities from outlying cities of significant but lesser population.

Feeder lines within 200 to 300 miles of major metropolitan airports could be a viable alternative to commuter and feeder airlines which currently add to air traffic congestion at these airports. These lines could also provide mail and other government services. Since such transportation systems would be in direct competition with the major airlines, it seems appropriate to involve the airline industry in the conceptualization and development of these possible systems.

As a final note, if Federal highway rights-of-way are to be used for magnetically levitated transportation systems, it would seem necessary to elevate the support structures sufficiently high above the highway to minimize the cost of reconstructing overpasses and cloverleaf exchanges. Such elevated systems would provide interesting challenges to structural designers in providing automatic mechanisms for maintaining system alignment at reasonable costs.

In conclusion, I see considerable merit in the Federal government proceeding with a critical examination of magnetically levitated transportation systems along Federal highway rights-of-way, with the expectation that such studies could lead to the restoration of Federal government investment in the development of these systems. In view of growing interest in the United States for such systems based on developments in Japan and West Germany, the need to initiate assessment studies by the Office of Technology of Assessment, the Department of Transportation; and the Transportation Research Board of the National Research Council appears to be timely. Also, since there are many aspects of these transportation systems which resemble the airframes, avionics and control systems of highly sophisticated aerospace systems, the aerospace industry in the United States could play a vital role in cooperation with the national laboratories in greatly accelerating U.S. competitive position relative to Japan and West Germany. I believe there is still time. Generally, in systems this complex, it is the second or third-generation systems which best meet all of the requirements. Therefore, a government-funded program to aim at a second-generation system, using the advanced technologies under our control, could give the United States a strong position in the future international marketplace for "mag-lev" transportation.

I hope that these observations and comments will be of help to the subcommittee. Thank you.

0951i

September 26, 1988

II

100TH CONGRESS
2D SESSION

# S. 2072

To amend title 23, United States Code, to authorize the use of rights-of-way along Federal-aid highways for the construction of transportation systems that will be part of the Federal-aid highway system.

---

IN THE SENATE OF THE UNITED STATES

FEBRUARY 18 (legislative day, FEBRUARY 15), 1988

Mr. MOYNIHAN introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

---

# A BILL

To amend title 23, United States Code, to authorize the use of rights-of-way along Federal-aid highways for the construction of transportation systems that will be part of the Federal-aid highway system.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*

## FINDINGS

SECTION 1. The Congress finds that—

(1) congestion on the Nation's highway system poses serious maintenance problems;

(2) the petroleum-based transportation modes that use the highways pose serious environmental problems, including air and noise pollution;

(3) the additional construction of magnetic levitation systems as part of the highways would relieve existing maintenance problems caused by automotive vehicle use and would relieve environmental hazards such as air and noise pollution; and

(4) the construction of magnetic levitation systems as part of the highways would provide significant opportunities for economic growth and development in various regions throughout the country.

RIGHTS-OF-WAY FOR MAGNETIC LEVITATION SYSTEMS

SEC. 2. Chapter 1 of title 23, United States Code, is amended by adding at the end thereof the following new section:

**"§ 159. Rights-of-way for magnetic levitation systems**

"The Secretary shall prescribe regulations under which the States will be allowed to use rights-of-way along Federal-aid highways for the construction of magnetic levitation systems as part of the Federal-aid highway system, with particular emphasis in the extent to which such systems affect all aspects of building and maintaining such highways.".

○